VOL. 14, NO.

Electronic Design 28

THE MAGAZINE OF ESSENTIAL NEWS, PRODUCTS AND TECHNOLOGY

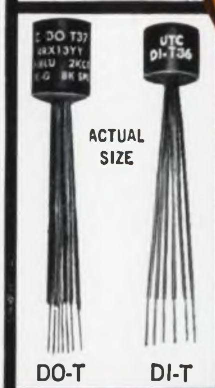
DECEMBER 6, 1966

A FET and relay in a TO-5? It's been done. This new device operates directly off low-level microcircuit logic. The n-channel FET—or if preferred a bipolar transistor—boosts tiny currents to the level required to trip the relay. The bantam driver-and-relay unit helps eliminate the problem of interconnections. (Page 118.)

AUDIO TRANSFORMERS

DO-T No.	Pri. Imp.	D.C. Ma.‡ in Pri.	Sec. Imp.	Pri. Res. DO-T	Pri. Res. DI-T	Mw Level	DI-T No.
DO-T44	80 CT 100 CT	12 10	32 split 40 split	9.8	11.5	500	DI-T44*
DO-T29	120 CT 150 CT	10 10	3.2 4	10		500	
DO-T12	150 CT 200 CT	10 10	12 16	11		500	
DO-T13	300 CT 400 CT	7 7	12 16	20		500	
DO-T19	300 CT	7	600	19	20	500	DI-T19
DO-T30	320 CT 400 CT	7 7	3.2 4	20		500	
DO-T43	400 CT 500 CT	8 6	40 split 50 split	46	50	500	DI-T43*
DO-T42	400 CT 500 CT	8 6	120 split 150 split	46		500	
DO-T41	400 CT 500 CT	8 6	400 split 500 split	46	50	500	DI-T41*
DO-T2	500 600	3 3	50 60	60	65	100	DI-T2
DO-T20	500 CT	5.5	600	31	32	500	DT-T20
DO-T4	600	3	3.2	60		100	
DO-T14	600 CT 800 CT	5 5	12 16	43		500	
DO-T31	640 CT 800 CT	5 5	3.2 4	43		500	
DO-T32	800 CT 1000 CT	4 4	3.2 4	51		500	
DO-T15	800 CT 1070 CT	4 4	12 16	51		500	
DO-T21	900 CT	4	600	53	53	500	DI-T21
DO-T3	1000 1200	3 3	50 60	115	110	100	DI-T3
DO-T45	1000 CT 1250 CT	3.5 3.5	16,000 split 20,000 split	120		100	
DO-T16	1000 CT 1330 CT	3.5 3.5	12 16	71		500	
DO-T33	1060 CT 1330 CT	3.5 3.5	3.2 4	71		500	
DO-T5	1200	2	3.2	105	110	100	DI-T5
DO-T17	1500 CT 2000 CT	3 3	12 16	108		500	
DO-T22	1500 CT	3	600	86	87	500	DI-T22
DO-T34	1600 CT 2000 CT	3 3	3.2 4	109		500	
*DO-T51	2000 CT 2500 CT	3 3	2000 split 2500 split	195	180	100	DI-T51*
DO-T37	2000 CT 2500 CT	3 3	8000 split 10,000 split	195	180	100	DI-T37*
*DO-T52	4000 CT 5000 CT	2 2	8000 CT 10,000 CT	320	300	100	DI-T52*
DO-T18	7500 CT 10,000 CT	1 1	12 16	505		100	
DO-T35	8000 CT 10,000 CT	1 1	3.2 4	505		100	
*DO-T48	8,000 CT 10,000 CT	1 1	1200 CT 1500 CT	640		100	
*DO-T47	9,000 CT 10,000 CT	1 1	9000 CT 10,000 CT	850		100	
DO-T6	10,000	1	3.2	790		100	
DO-T9	10,000 12,000	1 1	500 CT 600 CT	780	870	100	DI-T9
DO-T10	10,000 12,500	1 1	1200 CT 1500 CT	780	870	100	DI-T10
DO-T25	10,000 CT 12,000 CT	1 1	1500 CT 1800 CT	780	870	100	DI-T25
DO-T38	10,000 CT 12,000 CT	1 1	2000 split 2400 split	560	620	100	DI-T38*
DO-T11	10,000 12,500	1 1	2000 CT 2500 CT	780	870	100	DI-T11
DO-T36	10,000 CT 12,000 CT	1 1	10,000 CT 12,000 CT	975	970	100	DI-T36
DO-T1	20,000 30,000	.5 .5	800 1200	830	815	50	DI-T1
DO-T23	20,000 CT 30,000 CT	.5 .5	800 CT 1200 CT	830	815	50	DI-T23
DO-T39	20,000 CT 30,000 CT	.5 .5	1000 split 1500 split	800		50	
DO-T40	40,000 CT 50,000 CT	.25 .25	400 split 500 split	1700		50	
DO-T46	100,000 CT	0	500 CT	7900		25	
DO-T7	200,000	0	1000	8500		25	
DO-T24	200,000 CT	0	1000 CT	8500		25	
DO-TSH	Drawn Hipermalloy shield and cover 20/30 db						DI-TSH

‡DCMA shown is for single ended useage (under 5% distortion—100MW—1KC) . . for push pull, DCMA can be any balanced value taken by .5W transistors (under 5% distortion—500MW—1KC) DO-T & DI-T units designed for transistor use only. U.S. Pat. No. 2,949,591; others pending.
§Series connected; §§Parallel connected
*Units newly added to series



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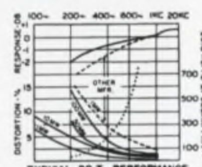
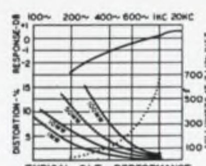

TYPICAL DO-T PERFORMANCE SOURCE: RATED PRI. IMP. AND D.C. LOAD: RATED SEC. IMP.


TYPICAL DI-T PERFORMANCE SOURCE: RATED PRI. IMP. AND D.C. LOAD: RATED SEC. IMP.

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- **Low Distortion** ......reduced 80%
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- **Printed Circuit Use** ......(solder melting) nylon insulated leads
- **Suited to Clip Mounting** ......use Augat #6009-8A clip

INDUCTORS

DO-T No.	Inductance Hys @ ma	DO-T DCRΩ	DI-T DCRΩ	DI-T No.
*DO-T50 (2 wdgs.)	§.075 Hy/10 ma, .06 Hy/30 ma §§.018 Hy/20 ma, .015 Hy/60 ma	10.5 2.6		
DO-T28	.3 Hy/4 ma, .15 Hy/20 ma	25		
	.1 Hy/4 ma, .08 Hy/10 ma		25	DI-T28
DO-T27	1.25 Hys/2 ma, .5 Hy/11 ma	100		
	.9 Hy/2 ma, .5 Hy/6 ma		105	DI-T27
DO-T8	3.5 Hys/2 ma, 1 Hy/5 ma	560		
	2.5 Hys/2 ma, .9 Hy/4 ma		630	DI-T8
DO-T26	6 Hys/2 ma, 1.5 Hys/5 ma	2100		
	4.5 Hys/2 ma, 1.2 Hys/4 ma		2300	DI-T26
*DO-T49 (2 wdgs.)	§20 Hys/1 ma, 8 Hys/3 ma §§5 Hys/2 ma, 2 Hys/6 ma	5100 1275		

POWER TRANSFORMERS

*DO-T400	Pri 28V 380-1000 cycles, Sec 6.3V @ 60 ma
*DO-T410	Pri 28V 380-1000 cycles, 2-Sec 6.3 @ 30 ma each
*DO-T420	Pri 28V 380-1000 cycles, Sec 28V @ 20 ma (Isol. Electrostatic Shld.)

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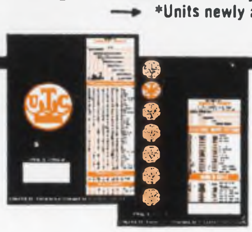

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ON READER-SERVICE CARD CIRCLE 3

VOL. 14, NO.

Electronic Design 28

THE MAGAZINE OF ESSENTIAL NEWS, PRODUCTS AND TECHNOLOGY

DECEMBER 6, 1966

NEWS

TECHNOLOGY

PRODUCTS

Departments

ELECTRONIC DESIGN is published biweekly by Hayden Publishing Company, Inc., 850 Third Avenue, New York, N. Y. 10022. James S. Mulholland, Jr., President. Printed at Poole Bros., Inc., Chicago, Ill. Controlled-circulation postage paid at Chicago, Ill., Cleveland, Ohio, and New York, N. Y. Application to mail at controlled postage rates pending at St. Louis, Mo. 60,777 copies this issue.

There's a G-E silicone

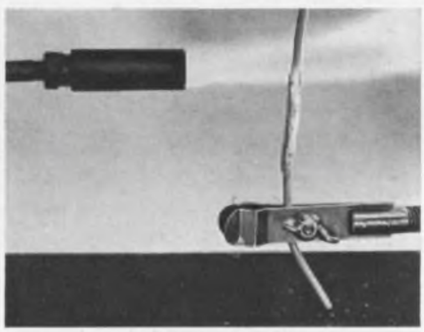
Bonding

Laminated layers of mica sheeting are securely bonded with G-E RTV silicone sealant. Ready to use, it bonds to most materials.

Screws and drilling are eliminated by adhering identification plates with RTV sealant. It won't harden, soften, crack or shrink.

Insulating

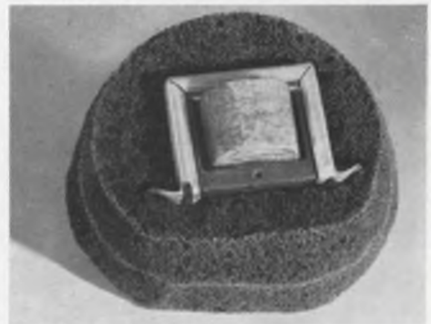
G-E RTV translucent sealant provides excellent see-thru insulation instantly. UL-recognized, the sealant also comes in colors.



Silicone rubber wire and cable insulation passes UL vertical flame tests and is frequently used in high-voltage circuits.

G-E silicone dielectric greases, ideal heat transfer media, are easily brushed, painted, sprayed, dip-coated or applied directly from tube.

Damping



G-E RTV-7 silicone rubber foams on the spot to provide mechanical support, shock and vibration damping, and light weight electrical insulation.

Sealing

G-E two-part RTV, available in a range of viscosities, seals filament condenser plate in dielectric heater. Also protects against vibration.

G-E RTV is ideal for high temperature moisture sealing of heating elements. It withstands temperatures as high as 600°F, as low as —75°F.

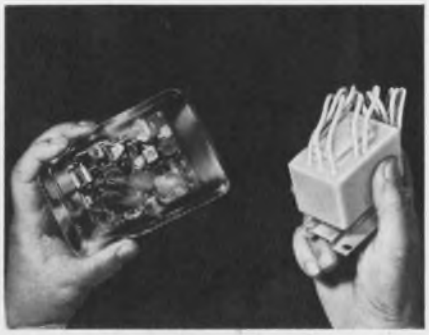
design solution for:

Moldmaking

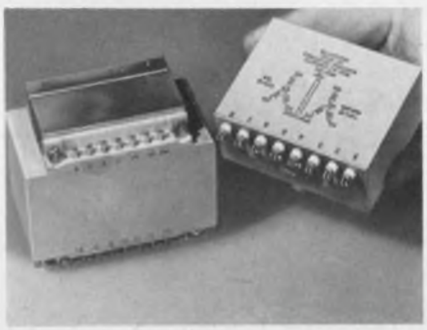
Tough, flexible G-E RTV silicone for moldmaking reproduces detail accurately and minimizes tooling costs.

For prototypes or short-run parts production, G-E RTV is an excellent flexible moldmaking material. And it needs no release agent.

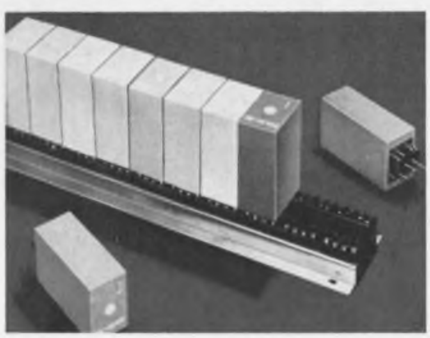
Potting and Encapsulating



Many G-E RTV silicone compounds are available—all with good strength, outstanding electrical properties and resistance to temperature extremes.



Impregnation of transformer coils with G-E RTV provides electrical insulation and environmental protection at high temperatures.



G-E RTV provides attractive, protective packaging for components. Each unit is encapsulated in a different color RTV for easy identification.

Fluids Applications

G-E silicone dielectric fluids provide excellent electrical properties and thermal stability for many types of components.

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G-E silicone elastomers are easily used to make numerous silicone rubber parts by standard rubber fabricating techniques.

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GENERAL ELECTRIC

ON READER-SERVICE CARD CIRCLE 4

new Tektronix plug-in simplifies reflectometry measurements

Type 1S2 Sampling Unit for time domain reflectometry and general-purpose sampling

You can test transmission lines, cables, connectors, broad-band devices with ease and accuracy with the new Type 1S2 Sampling Plug-In Unit. It can be used in any Tektronix oscilloscope that accepts letter and 1-series plug-ins.

The ≤90-ps risetime of the vertical channel, and deflection factors to 5 mV/div make the Type 1S2 useful in many general-purpose sampling measurements. For this general-purpose use, a pretrigger or delay line is required. System risetime as a reflectometer is ≤140 ps.

The illustration shows a Type 1S2 in a Tektronix Type 549 Storage Oscilloscope being used to test a 50-Ω delay line. Information obtained from the upper trace includes electrical length of the line, nominal impedance, location and type of discontinuities. Lower trace is magnification of the discontinuity shown near the center of the upper trace. Deflection factors:

Upper trace — Vertical 0.25 ρ/div
Horizontal 20 ns/div

Lower trace — Vertical 0.025 ρ/div
Horizontal 5 ns/div

The Type 1S2 Manual Scan display mode was used in storing both traces to obtain optimum resolution.

With the Type 1S2, positions of discontinuities in a line under test can be read directly from a dial in units of time or distance. Accuracy of round-trip time readings is within ±1% of full scale.

Dual, full-scale 10-division horizontal calibration is in distances of 10 m, 100 m, and 1 km, and in times of 0.1 μs, 1 μs, and 10 μs. The display can be expanded by a 7-step, calibrated, X1 through X100 magnifier for detailed examination of any discontinuities.

Illuminated readout of the horizontal scale factor, including any magnification, adds to the operating ease. And testing of either short or long lines is facilitated by internal generators that provide a 50-ps, 250 mV pulse and a 1-ns, 1-V pulse.

A front-panel switch provides for matching the horizontal calibration to the types of lines most commonly tested—air, TFE, and polyethylene. A variable control permits matching the calibration to lines using other dielectrics.

Vertical calibration is in both ρ(rho) and in volts, from 0.005/div to 0.5/div, in 7 steps, with an accuracy within ±3%. It is also variable between steps, uncalibrated. A ±2-V offset voltage, monitorable at the front panel, allows amplitude measurements, using slide-back techniques, with an accuracy within ±1%.

Vertical and horizontal outputs of 1 V/div of displayed signal are available at front-panel connectors.

Type 1S2 . . . . $1300
Includes: 2X and 5X attenuators, 50-Ω termination, 20-cm airline, 5-ns RG 8/AU cable, 2 GR elbows, 18" patch cord, and 2 manuals.

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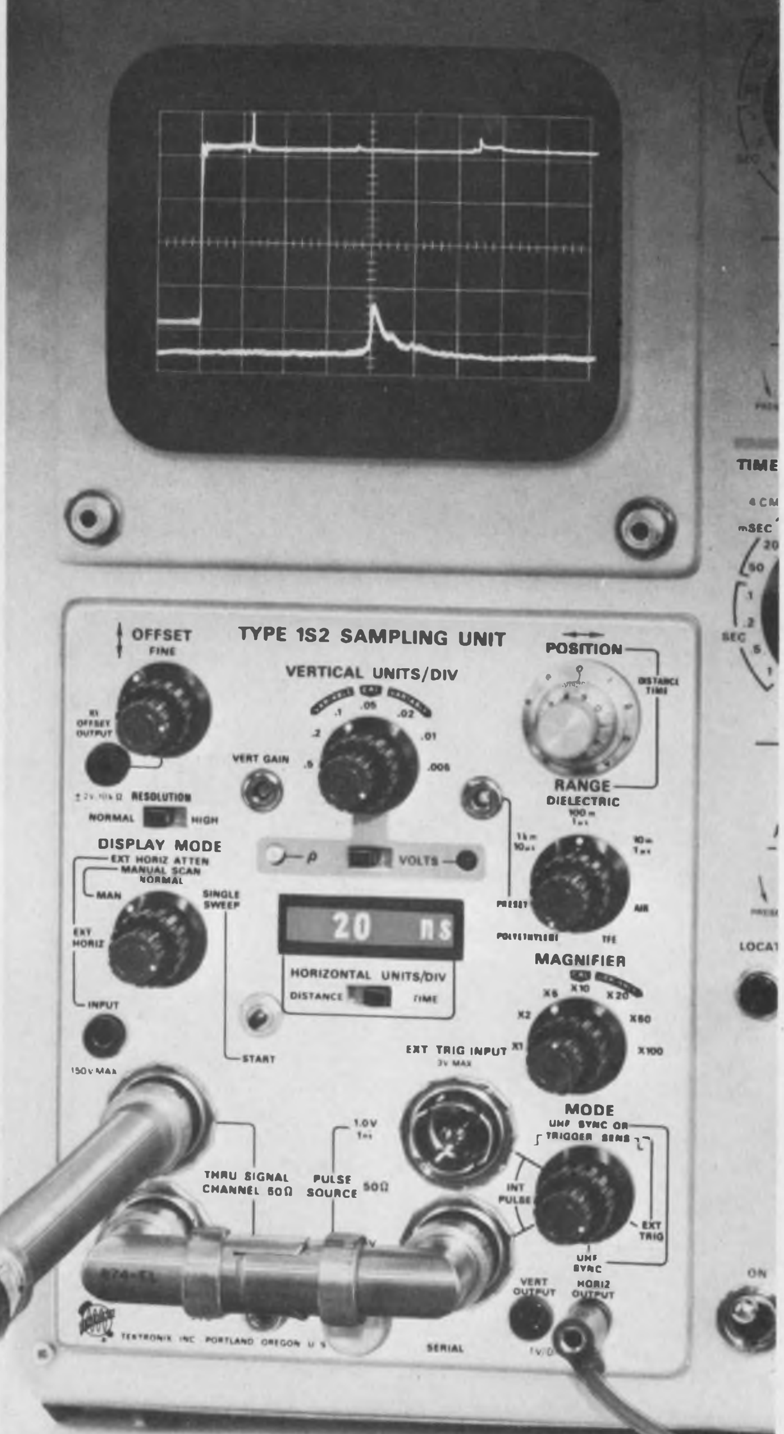

Tektronix, Inc.

For complete information, contact your nearby Tektronix field engineer or write: Tektronix, Inc., P.O. Box 500, Beaverton, Oregon 97005

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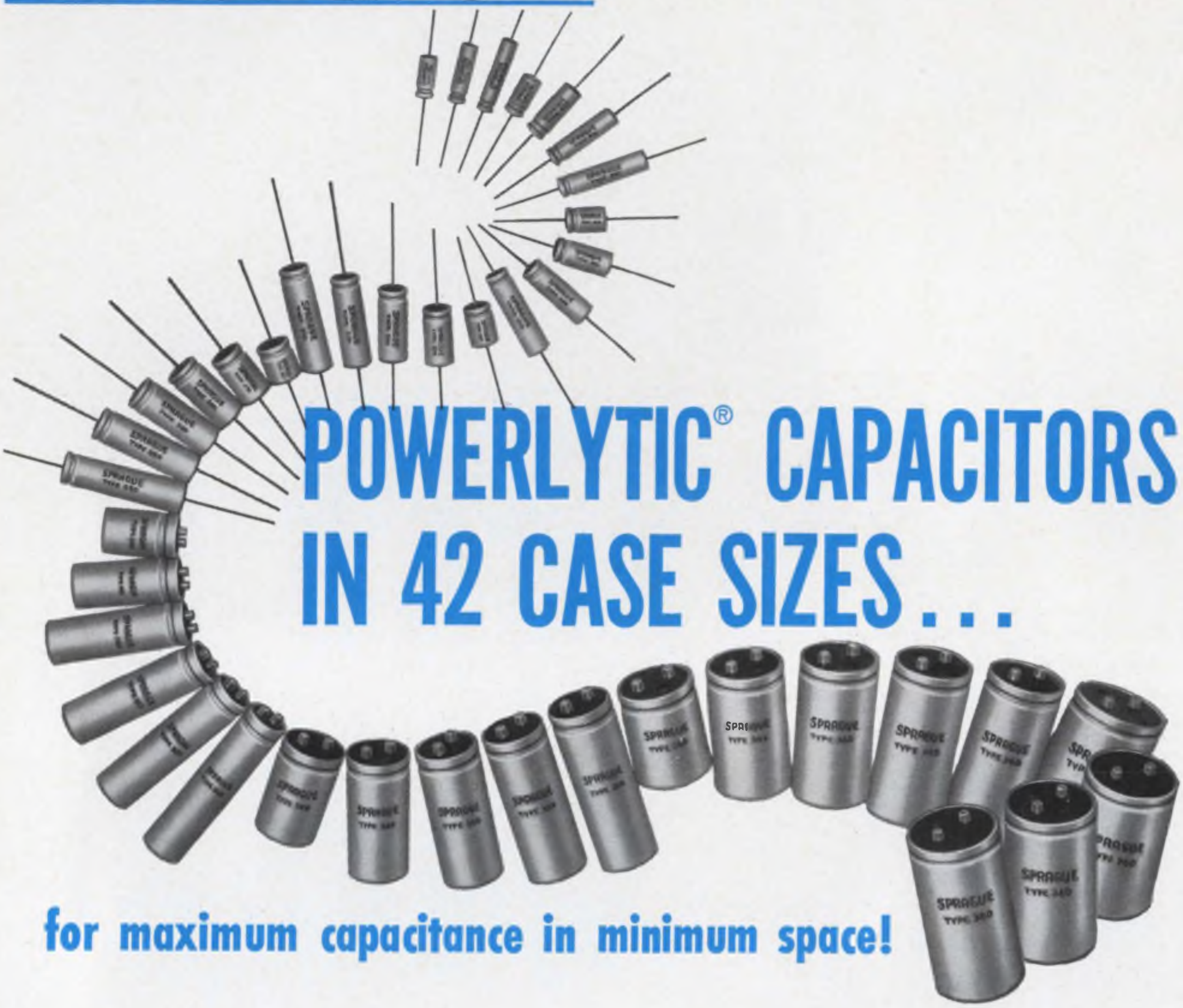

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For complete technical data on Type 36D or Type 39D Powerlytic Capacitors, write for Engineering Bulletins 3431B and 3415, respectively, to Technical Literature Service, Sprague Electric Co., 347 Marshall Street, North Adams, Mass. 01247.

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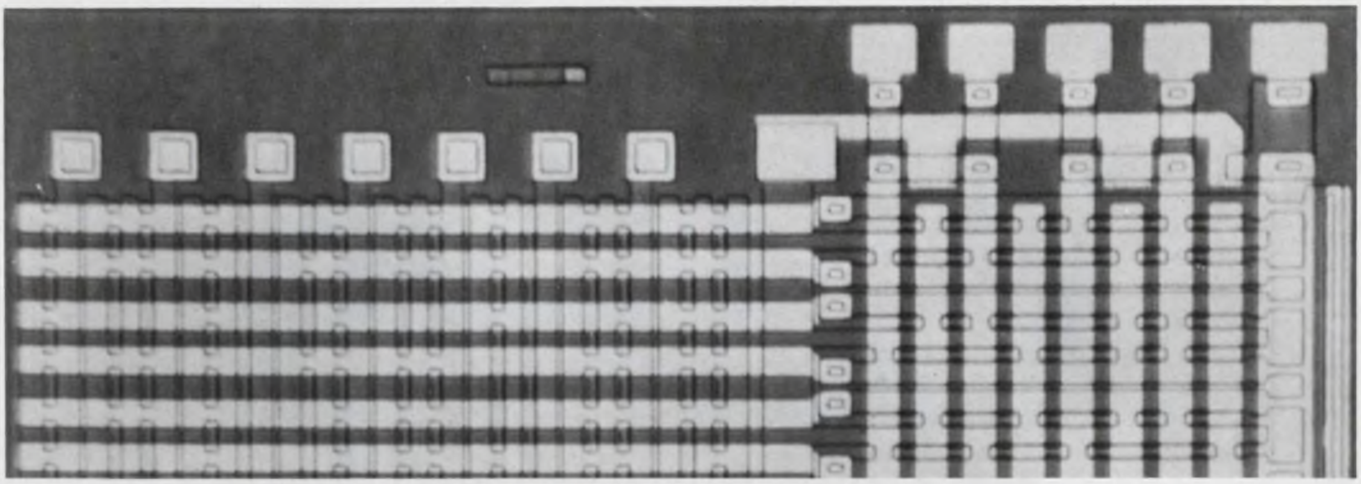
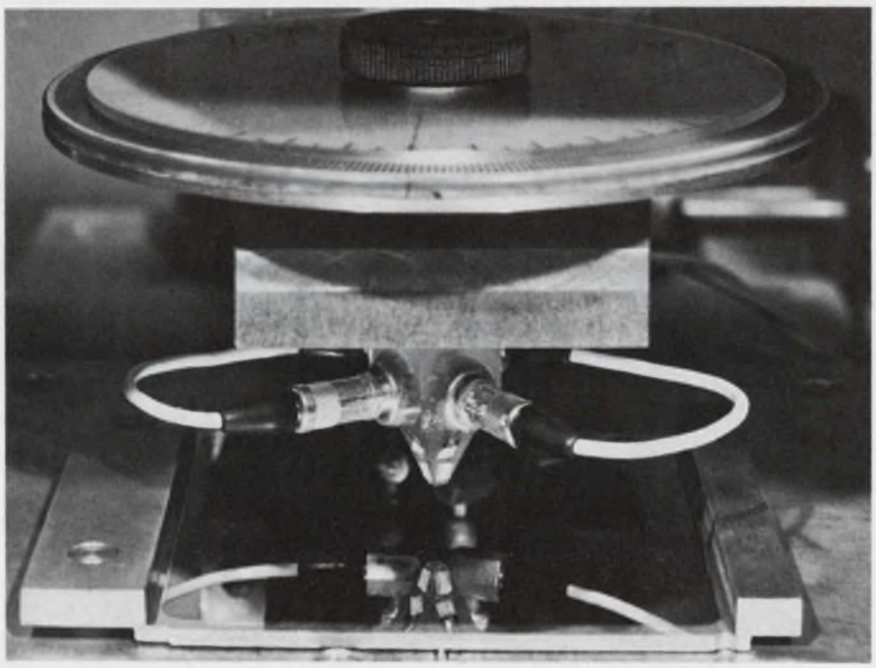
ON READER-SERVICE CARD CIRCLE 9

News



Large-scale integration makes a great impact on digital computers by upping the reliability of systems and power of data processors, while also cutting hardware costs. Page 17

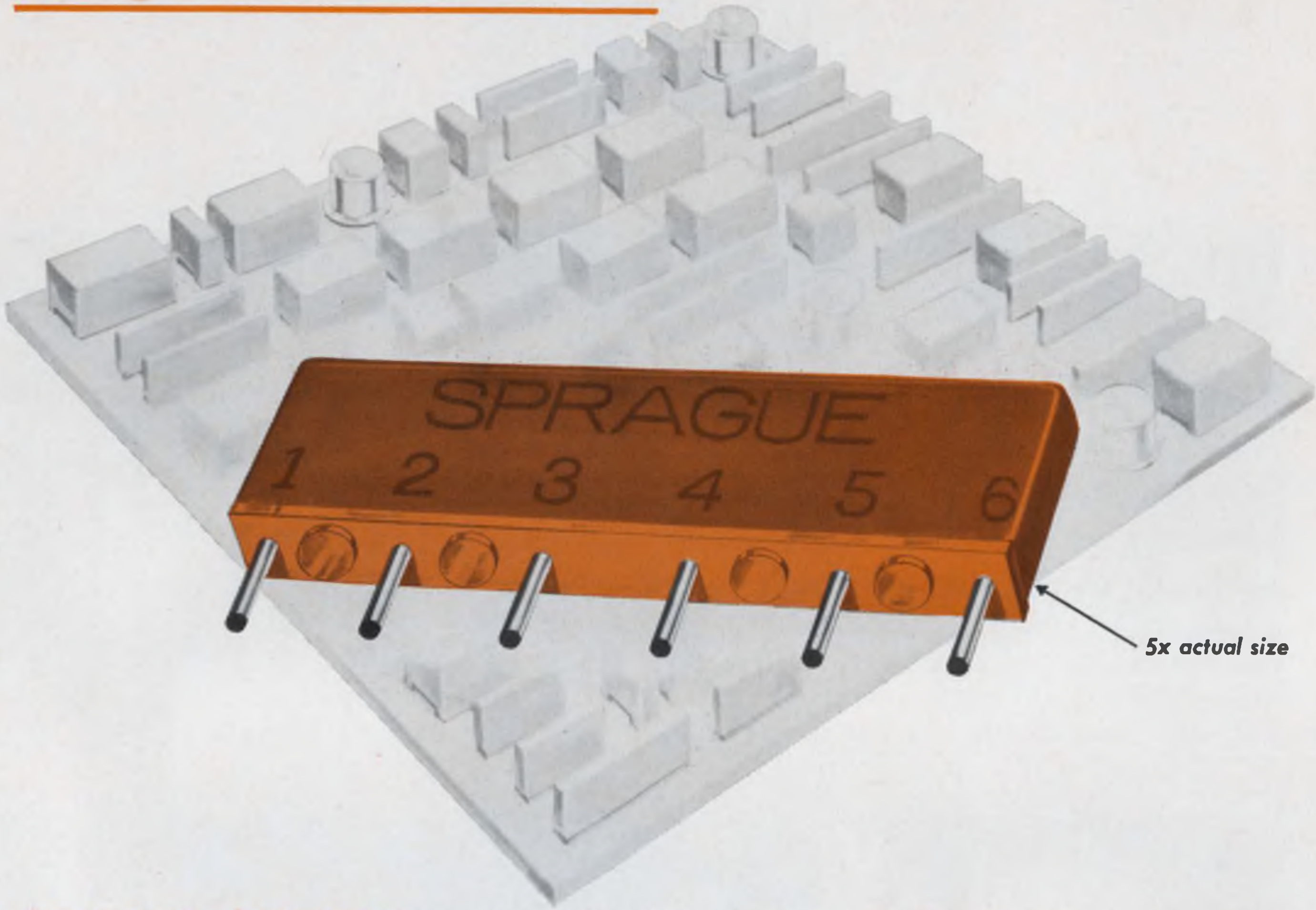
Electronic systems put new zip into tiny models. Page 24



Microprobe is able to check tiny magnetic domains in order to judge the suitability of films for computer memories. Page 38

Also in this section:

In High-Volume Production!



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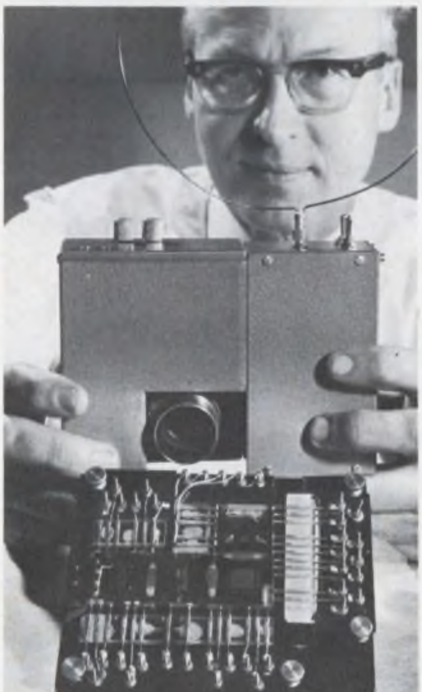
ON READER-SERVICE CARD CIRCLE 10

Tubeless TV cameras oust vidicon? not yet!

Despite increased effort by large companies to develop a solid-state tubeless television camera, it is still too early to predict the demise of the vidicon.

The developmental efforts received added impetus with the recent announcement by the Radio Corp. of America of a new solid-state TV camera, designed by Dr. Paul K. Weimer and associates at the company's laboratories in Princeton, N. J. Both Fairchild and Westingouse disclosed comparable cameras in October during the IEEE Electron Devices Meeting in Washington, D. C.

The RCA thin-film unit is experimental; it was developed for the Air Force, hopefully for incorporation in reconnaissance systems. It consists of 32,400 microscopic dots of photoconductive material arranged in a 180-by-180 array on a square-inch glass side. Along two of the four edges of the image-sensing slide are two other slides, each with 540 thin-film transistors. The transistor networks are connected to the horizontal and vertical grid lines of the array. A fourth slide carries additional thin-film circuits required for various control functions.



RCA's hand-sized, tubeless TV camera

The camera is battery-powered. It draws only 3 watts at 14 volts dc, including the transmitter unit.

Dr. Weimer described the operation this way:

As the scene is focused on the sensing array, the electrical resistance of various photoconductive dots varies in proportion to the amount of light falling on them. A train of pulses sequentially applied to all 180 vertical grid lines produces current in each dot in proportion to the incident light intensity—the weaker the light, the weaker the current.

At the same time the transistors in the second array sequentially sample each of the horizontal grid lines. This discloses the conductivity pattern in the photoconductive dots to create the electrical facsimile of the original scene.

The sensing array is scanned in this fashion 60 times every second, a rate consistent with that of a conventional television camera.

Every time the array is scanned, the many currents and their relative positions are sensed and combined into a single fluctuating current that forms the output of the experimental camera. This output, amplified and converted to a microwave signal in the transmitter, is sent to a television receiver for display.

At present, according to Dr. Weimar, the experimental camera is inferior in resolution, sensitivity and speed to a conventional TV camera. However, he adds:

"We expect to overcome many of these limitations in the future, by adopting new circuit ideas and by developing photoconductive arrays with as many as 10 times more light-sensing elements as are used in this first, experimental model."

The Fairchild camera was described by researcher Gene Weckler at the IEEE meeting. It consists of 10,000 phototransistors and 10,000 MOS-FETs on a single chip a half-inch square.

Westinghouse's unit, Gene Strull told the same meeting, is an array consisting of 50-by-50 phototransistors, also a half-inch square. Strull indicated, however, that his work showed that an array with resolution of 200 lines per inch was entirely feasible.

But all of the new devices have a way to go before they can match the vidicon's resolution of 400 to 500 lines per inch, as well as its sensitivity and speed. The advantages of a solid-state vidicon are such, however, that a concerted effort to develop a successful one will undoubtedly continue.

As Dr. James Hillice, vice president of RCA Laboratories in Princeton, observes:

"Eventually cameras of this type could find the widest possible application in the military, in space, in medicine, in home and industry. There is still much work to be done, but the promise is definitely there."

Space-guidance laser will undergo testing

The practical laser spacecraft guidance system will move a step closer to realization as a result of a recently awarded contract.

NASA's Marshall Space Flight Center, Huntsville, Ala., awarded the contract to ITT's Federal Laboratories at Nutley, N. J. Simulated tests will be made of a prototype light-beam system intended to guide space vehicles in rendezvous and docking maneuvers.

ITT officials say that the optical system will be lighter and more compact, accurate and efficient than radar systems used.

Gallium arsenide laser arrays are used on each spacecraft for rendezvousing. After initial acquisition, one vehicle's optical system becomes passive.

The maneuvering spacecraft's laser pulses are returned by a reflective array on the passive craft. Angle, range and rate-of-closure information are converted by the maneuvering craft's computer into

News Scope CONTINUED

signals for controlling its attitude and propulsion systems.

ITT plans to use a mountain-top laboratory to house the passive vehicle's system and an aircraft flying over the laboratory to simulate the maneuvering spacecraft.

Upon successful completion of the mountain-top tests, the laser system will be tested in NASA's Gemini rendezvous simulator and Lunar Excursion Module simulator.

80-kW accelerator being used by NBS

One of the world's most intense electron beams is being produced by a new linear particle accelerator (linac) at the National Bureau of Standards laboratory complex at Gaithersburg, Md.

With an electron power output of more than 80 kW—an intensity 200,000 times greater than any previously available at the bureau—the beam can infuse materials of all kinds with extremely high radiation doses.

The linac is basically a 100-foot pipe through which electrons are accelerated on the crest of a traveling radio-frequency wave. Individually powered accelerator sections are coordinated and used to impart high energy to the electrons by means of repeated voltage applications. The NBS linac has nine such accelerator sections that the beam passes through.

A long look at 100-foot accelerator

Since it is hard to maintain steadily the high RF power necessary for an intense linac beam, the NBS linac beam is pulsed. Each electron pulse is synchronized with a burst of RF energy within the accelerator sections. The electron bunches within a pulse travel on the crests of the RF field as they are moving down the accelerator.

The linac wing occupies two basement levels at the NBS complex. On one level are the linac chamber, a magnet room and measurement rooms; on the other level are cooling, power and control rooms.

The linac's well-defined beam, highly stable and extremely small in energy spread, can be controlled by magnetic fields and made to interact directly with various materials. Alternatively, it can be directed at certain targets to generate other radiations, such as X-rays, positrons or neutrons.

Are Russians checking Theory of Relativity?

The Soviet Union may be conducting experiments in space to check Einstein's Theory of Relativity.

This speculation arose from the recent publication of a brief article in *Pravda*. It announced that the Russians had orbited an atomic clock of the ammonia type in Cosmos 97, launched Nov. 26, 1965.

Explaining possible uses of an ammonia frequency standard in a satellite, Soviet Academician N. G. Basov said that it "permits carrying on communications with space devices, control over them and transmission of telemetric information for very great distances."

"In addition," he noted, "there is in this case a considerable increase in the operating precision of program timer devices and systems for determining the trajectory of the satellite's movement."

U.S. observers are speculating that the Cosmos 97 payload may be a prelude to checking Einstein's theory, by comparing the difference in performances of a space-born and a ground-based atomic clock. Such experiments have been suggested in the past by both Soviet and U.S. scientists.

The frequency of the satellite standard has been telemetered for comparison with a ground-based standard, *Pravda* reported. However, no quantitative data were reported, to show the amount of deviation experienced.

DOD will issue catalog for space experimenters

For researchers with an experiment that simply "must" be carried into space aboard the next Titan or Saturn launch vehicle, the Defense Dept. has just the thing: a new semiannual catalog of secondary payload space and flight opportunities for experimenters.

The catalog will be issued shortly by the Directorate of Defense Research and Engineering, according to Dr. Finn J. Larsen, deputy chief of the directorate. He told a recent meeting of the National Space Club that the publication would be part of a move to establish a central operating agency to manage flight support for all DOD space experiments. The program will be conducted in cooperation with a similar NASA effort to utilize unprogramed secondary payload space, Dr. Larsen said.

Integrated circuit used in FM receiver IF stage

H. H. Scott, Inc., announced that for the past month it has been using Fairchild Semiconductor integrated circuits in the IF amplifier stage of its higher-priced FM receivers. This is the first use of ICs in a high-fidelity home entertainment product, according to H. H. Scott.

Designated μA703, the amplifier consists of five transistors and two resistors deposited on a single silicon chip mounted in an epoxied package. Four amplifiers are used in each FM.

The use of an integrated circuit as an IF amplifier will, H. H. Scott says, improve the FM receiver's capture ratio (the ratio of desired signal to unwanted interference and other stations on the same channel).

Fairchild Semiconductor says that it plans to offer the device on the regular off-the-shelf market.

LSI chips away at computer hardware costs

Powerful logic functions on a slice promise higher reliability as well as size and cost reductions.

Joseph J. Casazza
Technical Editor

Successful development of large-scale integration (LSI) technology is making significant changes in digital computers. Some of these changes, according to Richard L. Petritz, director of Texas Instruments' Semiconductor Research and Development Laboratory, Dallas, are:

- Lower system hardware costs.
- Higher system reliability.
- More powerful data processors.
- Incorporation of software into hardware, with a resultant simplification of software.

Slice holds complete function

Incorporation of a complete function (adder, register, etc.) on a single circuit chip will have a great impact on computer design, Petritz points out. The present integrated-circuit approach permits incorporation of only a sufficient number of logic circuits to perform a part of some logic function. But as more complex logic functions are placed on a single slice of semiconductor material, computer software, too, can be simplified. The software will employ hardware to perform specialized operations that would otherwise require complex and expensive programs.

Integrated-circuit chips which contain a complete logic function are referred to by Petritz as integrated equipment components (IECs) to distinguish them from single-function ICs. The difference between these is illustrated in Fig. 1, which shows the relationship between a single device, IC and IEC.

There is general agreement that LSI, or "complex arrays," will be the big difference between third-generation and fourth-generation computers.

What are the logic functions that can be handled by LSI? According to L. C. Hobbs, president of Hobbs Associates, Inc., Vista del Mar, Calif., many functions that are presently handled by programed subroutines can be implemented easily with special-purpose circuits to perform the logic. Some of the functions that could be dealt with in this manner include:

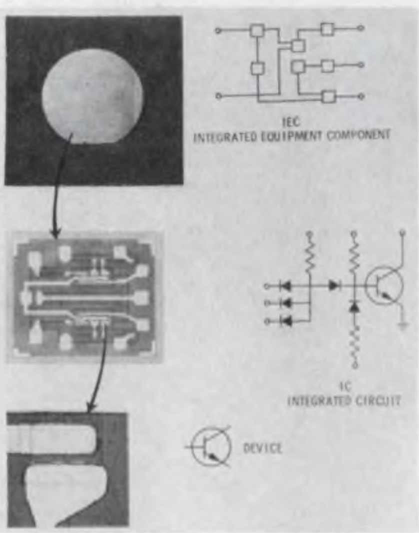
- Binary-to-decimal and decimal-to-binary conversions.
- Code conversions.
- Co-ordinate conversions.
- Format control.
- Table look-up operations.
- Scaling.
- Mathematical operations such as square root, trigonometric functions and matrix operations.

MOS or bipolar?

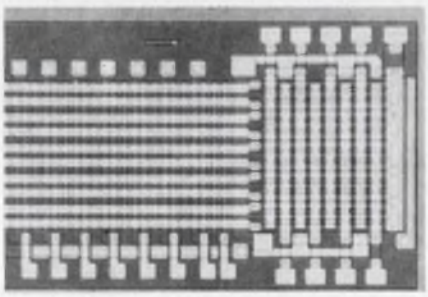
While the future role of LSI may be well established, the choice of device to implement this technology efficiently remains a major question. Will it be the MOS or the bipolar transistor? In answer, Petritz points out that MOS devices provide five times the amount of circuitry possible with bipolar transistors for a given surface area. "But," says Petritz, "the bipolar has a speed and power advantage." This, he believes, will offset the MOS device's size advantage in high-performance computer applications. This speed/power capability will give the bipolar transistor a role in the large, general purpose computer.

For those applications where MOS has sufficient speed and current handling capability, it should be used on the basis of achieving higher complexity per unit of chip area. Examples today include shift registers in the megacycle speed range where the capacity loading of devices is small because the fan-out is basically one. Some remarkable achievements have already been made in employing serial logic with MOSs for small processors such as desk calculators.

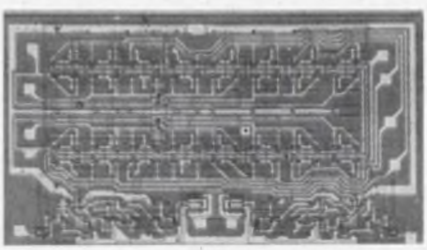
On the other hand, says Petritz, bipolar will be the choice for the



1. **Integrated equipment components perform complex logic functions** (top) as opposed to conventional integrated circuits (middle) which perform simple logic functions. These, in turn, are compared with the single transistor (bottom) which cannot perform any function independently.



(a)



(b)

2. **Examples of present-day IECs** include this eight-bit shift register (a) and this binary-decimal decoder (b), both built by Texas Instruments.

(LSI chips, *continued*)

more general applications, particularly if speed is a factor. The basic advantage of the bipolar is its inherently high transconductance (g_m); therefore, it is superior where appreciable capacitance must be charged as in parallel logic.

Comparison of the size and performance characteristics of both bipolar- and MOS-based IECs is shown in the table. Two of the devices listed—an eight-bit bipolar shift-register and a binary-decimal decoder—are shown in Fig. 2.

Designer's role changing

As the complexity of integrated circuits changes, the computer designer can reasonably expect to find his own role in the design process changing. Wendell B. Sander, of Fairchild Semiconductor's Research and Development Laboratory, Mountain View, Calif., believes that the designer will still have to make the decision to "buy standard, design custom, or build your own." This is a problem that must be faced when dealing with both conventional integrated circuits and their more complex counteparts. Where a computer designer had easy access to a number of complete integrated-circuit families incorporating the basic logic functions (AND, OR, etc.), he could adapt standard components to meet his needs. With complete functions on a single chip, however, the designer is now faced with the problem of using a readily available function and modifying his original design, or on the other hand proceeding with his original design and having special integrated circuits designed and built for him. cuits designed and built for him.

The question of whether or not to standardize complex logic-function families is of primary concern both to device and system manufacturers. Cost will certainly play a large role in any decision. Pointing to the large savings from the standardization of conventional integrated circuits, Dr. Robert N. Noyce, vice president of Fairchild Camera and Instrument, states that "the appearance of more standard arrays seems inevitable."

Increasing use of complex integrated computer circuits should simplify the designer's job and permit him to build a more powerful, more compact and less costly machine. There will be even less emphasis on the design of individual circuits and more on the synthesis of complex logic functions that are at present contained in software.

Another effect of LSI on the designer's job will be to increase the importance of design by computer. According to Petritz there are two approaches to computer-aided design of complex integrated circuits. One of these involves computer-aided design directly at the device level—that is, designing IECs by computer directly from device parameters. This is essentially the procedure followed by engineers today when approaching LSI through device-based design. Petritz believes, however, that a more useful approach will be to use computer-aided design at the circuit-function level. In this case the designer defines a set of logical circuits such as gates, flip-flops, etc., and uses the computer to design circuit layouts which minimize crossovers, area, etc.

Design by computer should benefit system manufacturers by shortening the time it takes for a device manufacturer to respond to system requirements. Another advantage of automated design techniques is that more accurate simulation for circuit analysis is possible with digital computers than with breadboarding. Normal breadboarding techniques do not simulate the actual conditions on a slice of silicon sufficiently well.

The material in this article is based on a series of papers delivered at the Fall Joint Computer Conference, held in San Francisco, November 8 through 10. Copies of the Conference proceedings may be purchased from the Scientific and Technical Division of Spartan Books, Inc., 432 Park Avenue South, New York, N.Y. 10016. A cumulative index is available also at a cost of $3.00. ■ ■

Table. Comparison of integrated equipment components

Mfr.	Component	Device	Area (in^2)	No. of devices	Device density ($devices/in^2$)	Speed	Power (mW)	Pads
*TI	Series-53 array	Bipolar	0.7	1200	1720	35 ns	1200	60
TI	8-bit shift reg.	Bipolar	0.006	160	26,500	15 MHz	190	6
TI	Honeywell memory	Bipolar	0.0071	100	14,000	25 ns	250	14
TI	Parallel-load serial shift	Bipolar	0.01	150	15,000	25 ns	270	22
†GME	100-bit shift reg.	MOS	0.0065	613	94,500	1 MHz	200	12
‡GI	21-bit shift reg.	MOS	0.0042	158	37,600	500 kHz	150	11
TI	22-bit shift reg.	Bipolar	0.0126	350	27,800	3 MHz	35	8
TI	B-to-D decoder	MOS	0.0057	152	26,700	200 kHz	25	26

*Texas Instruments, Inc. †General Micro-Electronics, Inc. ‡General Instrument Corp.

Spinning ball–heart of inertial system

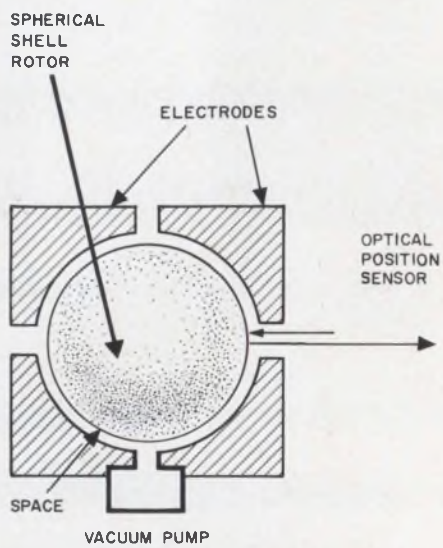
A spinning ball in place of a conventional gyroscope at the heart of a new airborne inertial guidance system has overcome a lot of friction and drift problems. The beryllium golf-ball-sized rotor "floats" in an electrostatic field as it spins at 60,000 rpm and furnishes a stable reference.

The use of electrostatic suspension combined with the elimination of the contact surfaces of the conventional gyro permit the ball to spin undisturbed in an evacuated chamber for periods up to three years.

The gyro was developed by Honeywell, Inc., under contract to the Air Force's Avionics Laboratory at Wright-Patterson AFB, Ohio. It is intended as part of the stabilized platform on C-124 aircraft.

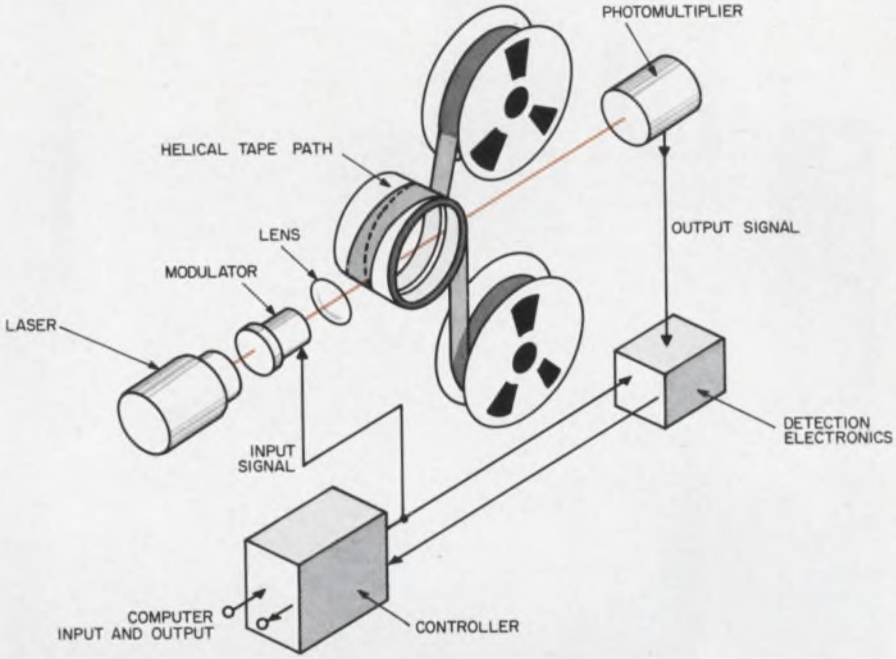
Air Force engineers say that the electrostatic suspension eliminates friction, the main source of inaccuracy in conventional gyroscopes, and gives a high degree of reliability.

The position of the spin axis of the sphere with respect to the gyro case indicates the orientation of the gyro in inertial space. A beam of light focused on lines inscribed on the sphere gives this reference. The platform's guidance computer uses data on the relative positions of the lines and the case. ■ ■



Ball replaces wheel as the rotor in a new electrostatic gyroscope.

Memory process puts 645 million bits on a square inch



Mass memory process uses lasers to write, check and read records. The laser burns minute data bits on fast-moving opaque plastic tape.

A new laser memory process is said to be able to pack 645 million bits of digital data on one square inch area of plastic tape. The laser burns minute craters in the tape, as the tape is drawn at high speed past an aperture.

The process was developed under Dr. Carl Becker of the Precision Instrument Co., Palo Alto, Calif. A laboratory model, without the tape-moving mechanism, has demonstrated the functions, but a complete system has yet to be built.

A one-watt cw argon laser, gated by an electro-optical modulator, burns the minute pits in the tape's opaque coating. The holes or the lack of them correspond to digital input data. A hole represents logical *1* and no hole is a logical *0* bit.

The operating system will move polyester tape around an imaging circle of the laser aperture. The aperture is formed by objective lenses rotating at 1800 rpm.

The laser creates one-micron holes (0.0039 inch) in the opaque coating of the tape, leaving the clear backing intact. The holes are burned in successive parallel lines slanted at a slight angle across the tape. This permits the entire tape surface to be used and results in the high storage density.

A locating track in binary code is used to locate each individual track for readout.

Light passing through the clear spots in the tape is used to verify the accuracy of the process. A plexiglass "light pipe" collects and transports light passing through the tape to a photomultiplier, where it is translated to electrical impulses. The impulses are then compared with the input data to verify the recording.

The tape is read by the reverse of the writing process. A lower-powered cw laser beam illuminates the tape as it rolls by. Light shines through the holes and is translated into an electrical pulse. The reading laser does not alter the tape. Pulses can then be fed to a computer, printer or other recorder.

According to the Precision Instrument Co., the new process is unique in the following ways:

- The capacity is 645 million bits per inch. This compares with about 5600 bits per square inch for standard magnetic tape.
- The speed-recording rate is 12 million bits per second.
- Permanence-holes cannot be erased and do not fade.
- The accuracy of the recording is verified instantly, and an alarm indicates lack of correspondence between input and output. ■ ■

Bureau of Standards calibrating peak-pulse instruments

Need to have your peak-pulse voltmeter calibrated? Try the Radio Standards Laboratory of the National Bureau of Standards, Boulder, Colo.

The bureau recently announced a new service, which it said is capable of calibrating various types of instruments, such as meter and digital units and oscilloscopes. Pulse generators can also be calibrated, provided their controls can be set accurately to some reference position.

Peak voltages, the bureau said, can be determined over the range of 5 to 1000 volts. Measurements are made to ±1% with accurate fast rise, unidirectional, trapezoidal pulses.

The parameters of these pulses for the different voltage ranges are as follows:

Voltage Range	**5 to 100 V**
Rise and Fall Time	10 ns (each)
Pulse Duration	0.02 to 100 μs
Pulse Rep. Rate	60 to 2 X 10^6 pps
Max. Duty Cycle	0.1
Voltage Range	**100 to 1000 V**
Rise and Fall Time	30 ns (each)
Pulse Duration	0.06 to 5 μs
Pulse Rep. Rate	60 to 1.66 X 10^6pps
Max. Duty Cycle	0.01

Any questions about calibrations within these specifications or about special calibrations not covered in the two voltage ranges should be directed to Philip A. Simpson, High Frequency Calibration Services, Engineering Division, Radio Standards Laboratory, National Bureau of Standards, Boulder, Colorado 80302. ■ ■

NEWS

Dual magnetometers help search for oil

If you happen to see a helicopter flying low with two bomb-shaped devices dangling below it on a cable, don't be alarmed. Its intentions are peaceful. It is merely looking for oil.

The new airborne surveying instrument, known as a geomagnetic gradiometer, has been developed by Varian's Quantum Electronics Div., Palo Alto, Calif. The instrument system is capable of mapping hundreds of square miles of subsurface terrain a day. It is said to be superior to the single magnetometer, now in common use.

The gradiometer system furnishes detailed data for use in determining the location of geological structures that trap petroleum under the ground. It is made up of two rubidium magnetometers in streamlined pods, suspended 100 feet apart vertically below an aircraft.

Each magnetometer senses changes in the earth's magnetic field as small as 0.01 gamma (about one part in five million) of the earth's magnetic field. Instrumentation within the aircraft simultaneously records the output of the lower magnetometer and the difference in signals between both.

By using two magnetometers, the new gradiometer is said to have the following advantages over the single magnetometer:

- Vertical measurement sensitivity to determine the character of the deep layers and their relation to probable oil-bearing strata.
- A sensor configuration that cancels the daily changes in the earth's magnetic field and prevents their distribution of measurement.

The basic element in each magnetometer is a glass cell containing vaporized rubidium. Optical pumping is used to excite the vapor. Changes in the vapor's energy level as the magnetometers pass through the earth's variable magnetic field are monitored optically.

Varian scientists are working on even more sensitive cesium and rubidium magnetometers expected to have a twentyfold improvement over current magnetometers. ■ ■

Bombs on a string? No, two magnetometer sensors. They are part of Varian's new geomagnetic gradiometer for finding oil deep in the ground.

Model-makers race, fly and sail with electronics

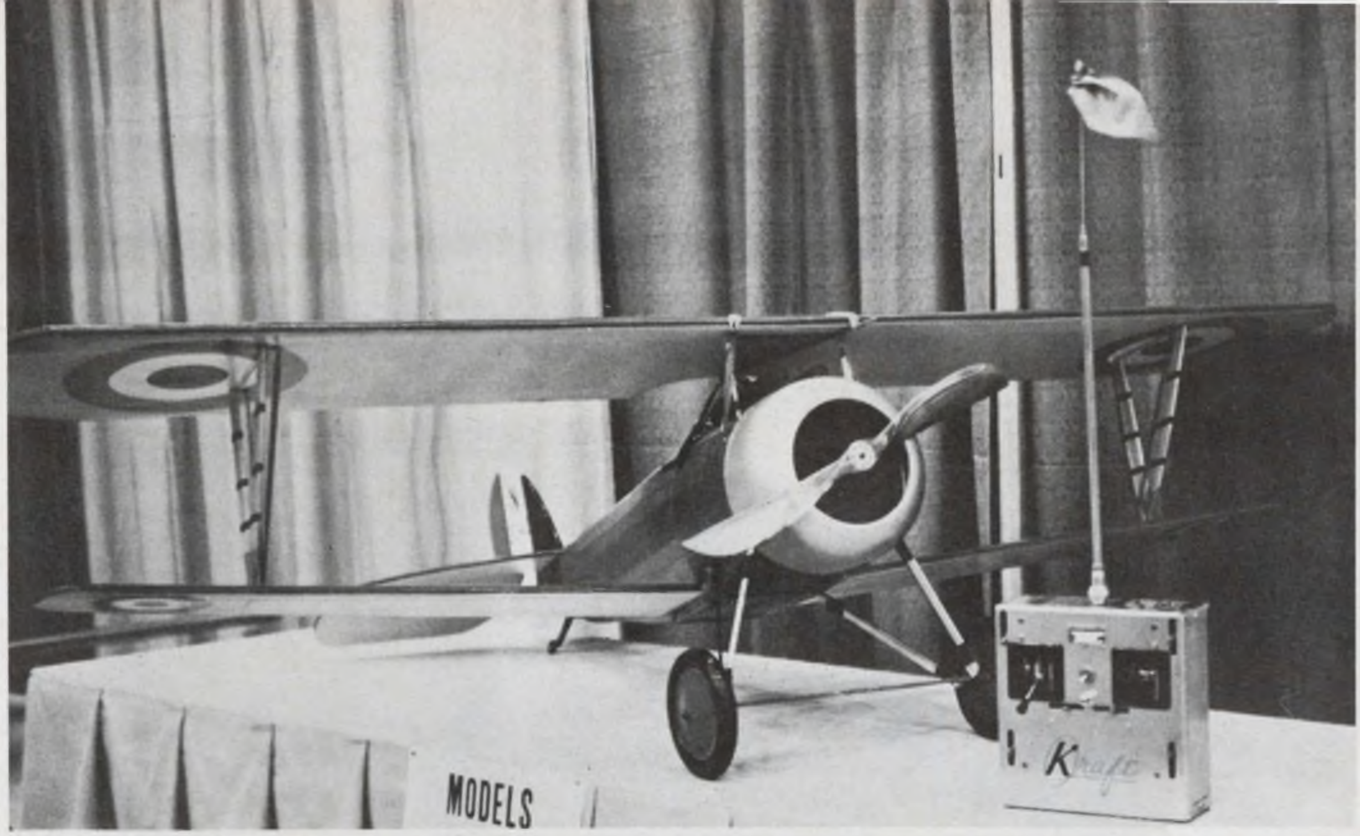
If you think that electronics is all work and no play, you weren't at the National Hobby and Craft Exposition held in New York's Coliseum at the end of October.

From finely detailed "slot racers" to a plastic, radio-controlled duck, electronically operated models drew considerable attention from show visitors of all ages. Not only are these pint-sized replicas accurate reproductions of the real thing but they can duplicate many of their prototypes' movements. Most of these were home projects. But the racing cars, such as the one shown here, and the Norelco kit ($25) are on the market.

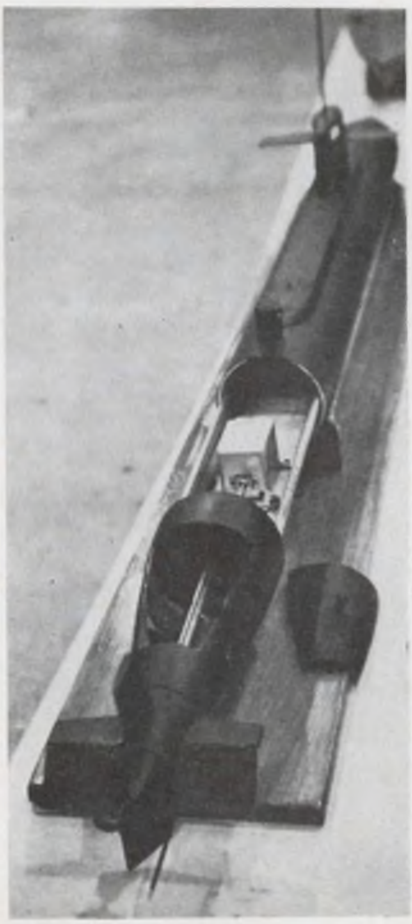
Joseph J. Casazza, Roger Kenneth Field

It'll never fly, but this colorful little bird will paddle about a pond under command from a miniature radio transmitter. Containing a tiny radio receiver, the duck is propelled by a small, battery-driven electric motor coupled to a propeller in its "stern." Rudder position is controlled by a miniature servo. He mixes well with other ducks.

Answer to the parking problem? Not really. This little car is one of the very popular slot-racers. Propelled by miniature dc motors and receiving their 12-volt power from metal-covered track "slots," these Lilliputian machines whiz around the track at blurring speeds. The next step may be radio-control. Integrated circuits could provide sufficiently small receivers, but nobody has yet come up with servos that can steer the car yet are at the same time small enough to fit "under the hood."



Blending past and present, this model of a World War I fighter contains electronic equipment that was unheard-of in the days of flying goggles and white silk scarfs. All control functions, including engine speed and wheel brakes, are incorporated in model aircraft such as this. The "pilot" flies his "bird" using the transmitter shown on the right. The little pennant on top of the antenna prevents spectators from poking an eye out.



For the man who wants something different, here's a radio-controlled submarine that will dive and surface. Small servos, operating at the command of a land- or rowboat-based transmitter, control the speed, direction and diving planes of this battery-driven undersea model.

Coauthor Casazza fingers a tune on this organ, built from a Norelco electronic projects kit. Armed with transistors and diodes, the experimenter can build a number of different gadgets by plopping a wiring diagram over the spring clips and hooking away.

A third slash for military R&D?

Washington Report

S. DAVID PURSGLOVE, WASHINGTON EDITOR

Military R&D faces another cut

Pentagon R&D programs face the budget axe for the third consecutive year. The military R&D slash in the 1968 fiscal budget, which will be presented next January and take effect in July, is expected to be the stiffest yet. Both the President and Defense Secretary McNamara have said that the new budget aims to eliminate every cent of Pentagon spending that is not absolutely essential. Budget Bureau officials say this generally means "not absolutely essential to the war in Vietnam." Marginal R&D programs face a death sentence.

McNamara underscored the policy of frugality at the time he announced Poseidon production. He said: "We considered the basic policy which we will follow as a foundation for the defense program in fiscal 1968, and, upon the President's instructions, will defer every possible element of the defense program that can be deferred without adversely affecting our security." Still, the total defense budget for 1968, not including an expected supplemental, is expected to rise $2 billion. Most of the increase will go to prosecute the war in Vietnam.

Congress to probe Federal computer use

The 90th Congress will take a careful look at the Government's use of computers, and the members of at least one committee hope improved application of computers will greatly cut the mounting pile of paperwork. More important, though, they hope to reduce the cost of using the computers.

Rep. Robert N. C. Nix (D-Pa.), chairman of the House Census and Statistics subcommittee, and Rep. Tom Murray (D-Tenn.), chairman of the parent Post Office and Civil Service Committee, are expected to introduce legislation that will greatly influence the Government's use of computers. For one thing, they want agencies to apply source data-automation methods more often. This should, they say, reduce the cost of preparing data to feed secondary computers. They point out that it now costs $550 million a year to program the input for the Government's computers.

They will also recommend a broad program of research on paperwork practices and systems. A new Federal center for research into paperwork may be set up. The Nix subcommittee recently issued a report on Federal paperwork and indicated strongly that all too often the use of computers in Government is creating more paperwork instead of cutting it. Nix singled out the storage problem created by computers that generate stacks of records 100 times faster than typewriters can. Research that would permit agency heads to forecast more accurately the implications of computerization is among the goals of the $500,000-a-year program recommended by the committee.

FCC may regulate computer rentals

The Federal Communications Commission plans to hold hearings that may lead to regulation of computer and computer-time rentals. The commission feels it has jurisdiction because input and output often are transmitted over telephone lines.

The FCC will try to determine under what circumstances computer services are subject to regulation under existing law, whether public policy requires the regulation of computer rental, and whether the Commission should recommend new legislation. It is especially concerned over the privacy of input and wants to find out what security measures the service companies take to protect their clients.

So far, says FCC chairman Rosel Hyde, there have been no reports of abuses. But he says the commission wants to avoid them in advance.

Holifield seeks procurement study

A two-year Congressional investigation of Federal procurement policies and practices will be proposed by Rep. Chet Holifield (D-Calif.) when Congress returns in January. Holifield is chairman of the Military Operations subcommittee of the House Government Operations Committee. He will introduce a bill to set up a two-year investigatory panel to study all aspects of Government buying.

As Holifield envisions it, the special commission would include representatives of Congress, the Executive and public life. It would have the power to examine virtually all records of Government contractors.

Billions in work up for grabs

As already disclosed, the electronic industry is expected to receive most of the $2.6 billion that probably will be spent over the next five years to refit Polaris submarines for Poseidon missiles. But the big questions are: Who will do the work? And where?

Officials at both the Pentagon and at Lockheed, the prime contractor on both Polaris and Poseidon missiles, say it is far too early to talk about electronics contractors for the modification program. However, they admit that present Polaris and Poseidon contractors undoubtedly have the edge, especially since the Defense Dept. apparently wants the work done quickly and at the lowest cost possible.

Aside from Lockheed, Aerojet and Hercules are associate contractors for Polaris power plants, and Thiokol and Hercules are associates for the Poseidon propulsion system. General Electric and Hughes are associates for Polaris guidance, as they are for Poseidon. Of the subcontractors selected so far, many of those for the Poseidon program filled the same roles in Polaris.

In the Polaris program, GE has a special relationship with the Navy as a separate contractor on the Mark 80 and Mark 84 fire-control subsystems, while Hughes is the fire-control subcontractor under Lockheed. Interstate Electronics, Inc., of Anaheim, Calif., is subcontractor for instrumentation. Five organizations hold a position called "sub-prime" for missile guidance: Raytheon, Massachusetts Institute of Technology, GE, Hughes Aircraft and Honeywell. Responsible for communications are Sylvania, RCA's Princeton Laboratories, Bell Telephone Laboratories and ITT Laboratories. Missile check-out is handled by Northrop's Nortronics Div. Sperry Gyroscope is responsible for the navigation subsystem.

Defense Secretary Robert S. McNamara says it will cost somewhat more than 60 per cent of the original cost of the subs to refit them. The Navy has 41 Polaris submarines, and the average cost of each is $104 million. Early models will need the most extensive modifications. Later subs were built to carry and launch the A-3 Polaris, and the Poseidon will be only three feet longer and 18 inches greater in diameter. Navy sources say the modifications to the launching tubes will be minor compared with the necessary changes in the electronics—guidance, check-out (in-tube status sensors) and arming systems. The decision to produce and deploy Poseidon is viewed here as McNamara's answer to the Soviet Union's antimissile system, now being made operational. The precept is that the best defense is a good offense. No official decision has yet been made public on whether to proceed with development of our own nuclear antimissile system, the Nike-X. Pentagon officials speculate that McNamara will not request production funds for it in fiscal 1968.

McNamara still feels that a massive, costly fallout shelter program must accompany the deployment of any system like the Nike-X system, because it will pepper as much radioactive fallout over the U.S. as invading enemy missiles would.

New experiments in space

Five Applications Technology satellites (designated AT-Bs officially) are to be launched by NASA, starting this month. An Atlas-Agena rocket will lob the spin-stabilized payloads into stationary orbits at the equator, 22,300 miles above the Pacific Ocean at 151 degrees West longitude.

The spacecraft will be capable of transmitting television (black and white and color) and narrowband communications between stations at Rosman, N. C.; Mojave, Calif.; Kashima, Japan, and Toowoomba, Australia.

A number of firsts will be among the experiments to be carried out on the satellite.

They include:

- VHF experiment for voice transmissions via the satellites to airplanes in flight.
- Transmission of high-quality cloud-cover pictures of the earth from synchronous orbit.
- Transmission of weather data (weather maps and nephanalyses) over a long-distance system.

RANGES

DC VOLTS: 0-0.15/0-.75/0-3/0-7.5/0-30/0-75/0-300/0-750/0-3000 @ 20KΩ/V; 0-0.3/0-1.5/0-6/0-15/0-60/0-150/0-600/0-1500/0-6000 @ 10KΩ/V.

AC VOLTS: 0-2.5/0-7.5/0-30/0-150/0-750 @ 10KΩ/V; 0-5/0-15/0-60/0-300/0-1500 @ 5KΩ/V.

DC MICROAMPS: 0-75 @ 150MV; 0-150 @ 300MV.

DC MILLIAMPS: 0-0.75/ 0-7.5/ 0-75/0-750 @ 150MV; 0-1.5/0-15/0-150 @ 300MV.

DC AMPS: 0-7.5 @ 150MV; 0-1.5/0-15 @ 300MV.

DB SCALE (L1MW-600): −20 to +75.5 db in 10 ranges.

OUTPUT: 0.1 mfd capacitor in series with all AC Voltage ranges through 300 Volts.

RESISTANCE: R×1, 0-500Ω; R×10, 0-5000Ω; R×100, 0-50KΩ; R×1K, 0-500KΩ; R×10K, 0-5 megΩ; R×100K, 0-50 megΩ(4.5Ωcenter).

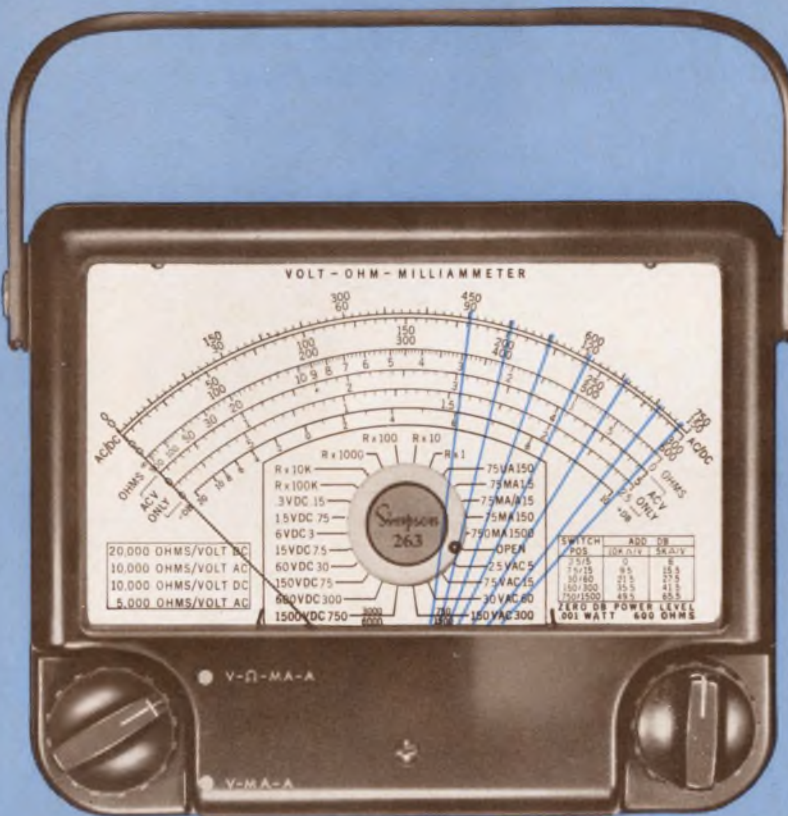
ACCURACIES

DC VOLTS: 0-0.15 to 1500 ±1½%; 0-3000 to 6000 ±2½%.

AC VOLTS: ±3%.

DC CURRENT: ±1½%

RESISTANCE: R×1, ±3° of Arc; R×10 and R×100K, ±2½° of Arc.



TWO OTHER SIMPSON DC/AC VOMs WITH INTERESTING CAPABILITIES

100,000 OHMS/VOLTS SENSITIVITY
MODEL 269-2
$90.00

33 RANGES
BIG 7-INCH SCALE
MODEL 262-3
$70.00

NEW SIMPSON 64-RANGE, 7-INCH SCALE VOM

Model 263—in stock for immediate delivery

With the improved, overlapping range coverage of Simpson's new 263 VOM, almost any value you want to measure can be read on the upper half of the scale (half to full scale). This results in a four to five times greater accuracy of reading. Other things you'll like about the 263 are its diode overload protection which prevents movement burnout at 200,000% overloads . . . 1½-volt alkaline battery that keeps low ohms readings extra stable . . . and its high accuracy. Sensitivities are 20,000 and 10,000 ohms/volt DC; 10,000 and 5,000 ohms, AC. The 263 is the newest member of Simpson's great family of VOM's with 7-inch meters. Order one from your Electronic Distributor, or write for Catalog 2074. Model 263, complete with test leads and operators manual, only. **$85.00**

TWO OTHER NEW SIMPSON DEVELOPMENTS! New contest for "260® VOM Applications" . . . new edition of "1001 Uses For Your 260 VOM" book. See your electronic distributor for details, or write direct.

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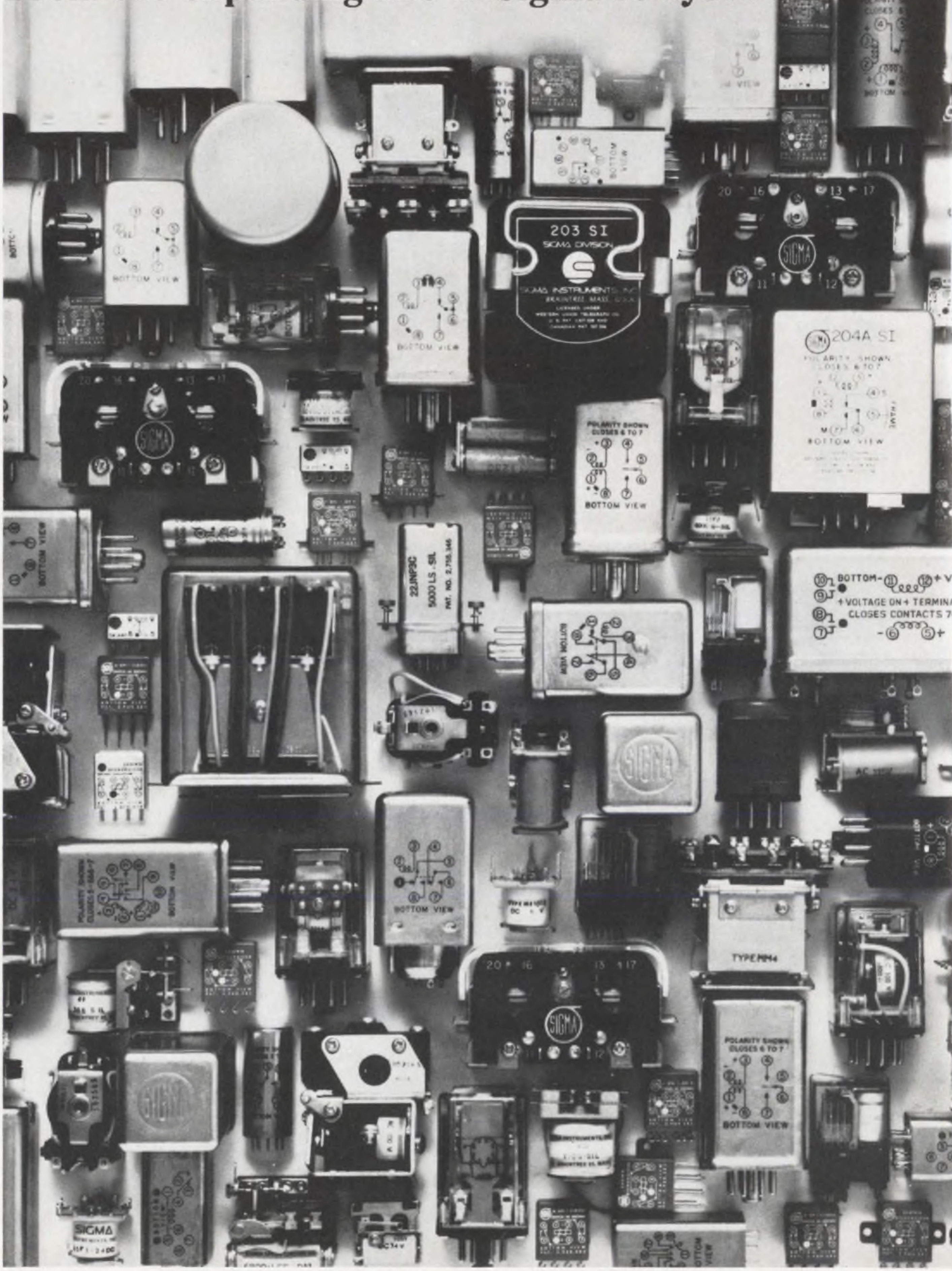
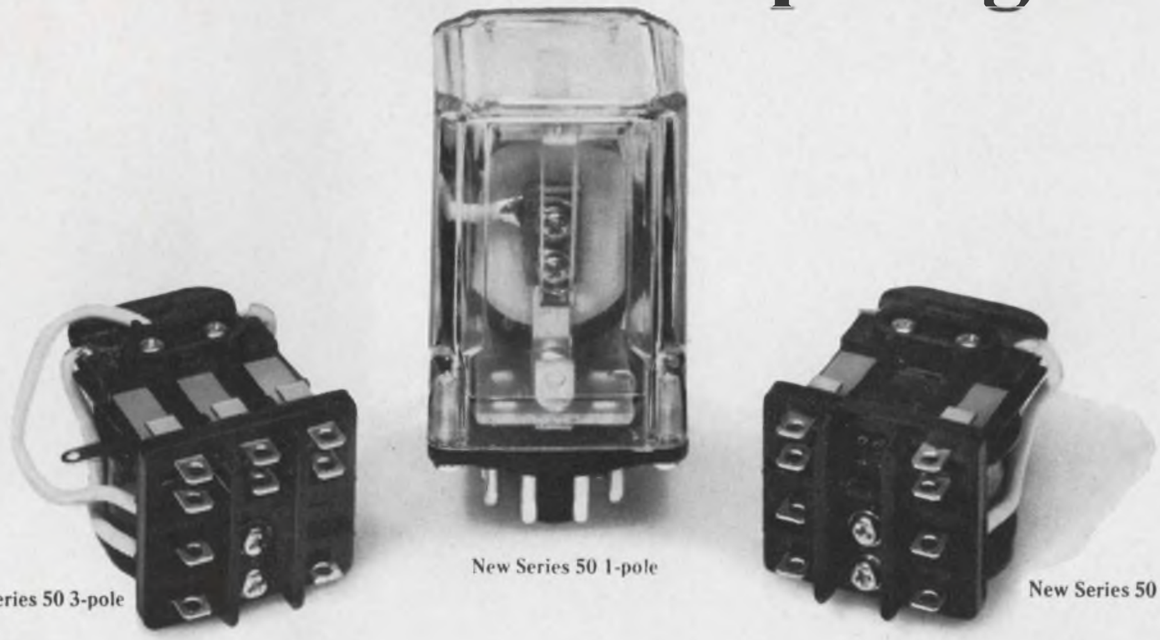
WORLD'S LARGEST MANUFACTURERS OF ELECTRONIC TEST EQUIPMENT

From the expanding line of Sigma relays . . .



New 1, 2 and 3 pole relays for nearly every application in the 5 and 10 amp range.



New Series 50 3-pole

New Series 50 1-pole

New Series 50 2-pole

Try one–or any Sigma relay–absolutely free.

We want to give you a new Series 50—or any standard Sigma relay—to use in an application you're working on now. We think it will outperform any other brand you may be using.

If you select the new Series 50 you can choose from 12 versions that cover every combination of its 1, 2 or 3 poles, 5 or 10 amp AC or DC power ratings, enclosed and open types, plug-in and soldered connections. These versatile relays are designed for the broadest variety of general purpose industrial applications ranging from output relays in sensing controls to photocopiers and vending machines.

The Series 50 is U. L. listed and includes such quality features as: Adjustable armature hinge for precise contact alignment. Heavy-duty contact base material for improved dielectric strength and insulation resistance. Single molded plug assembly with high temperature resistant polycarbonate housing.

Put the new Series 50, or any Sigma relay, to the test yourself, free of charge. Just send for the new Preferred Standard and Stock Relay Catalog of the expanding line of Sigma relays. Then select the relay you want to test and compare, and your Sigma representative will see that you get it. Offer limited to original equipment manufacturers having applications for relays.

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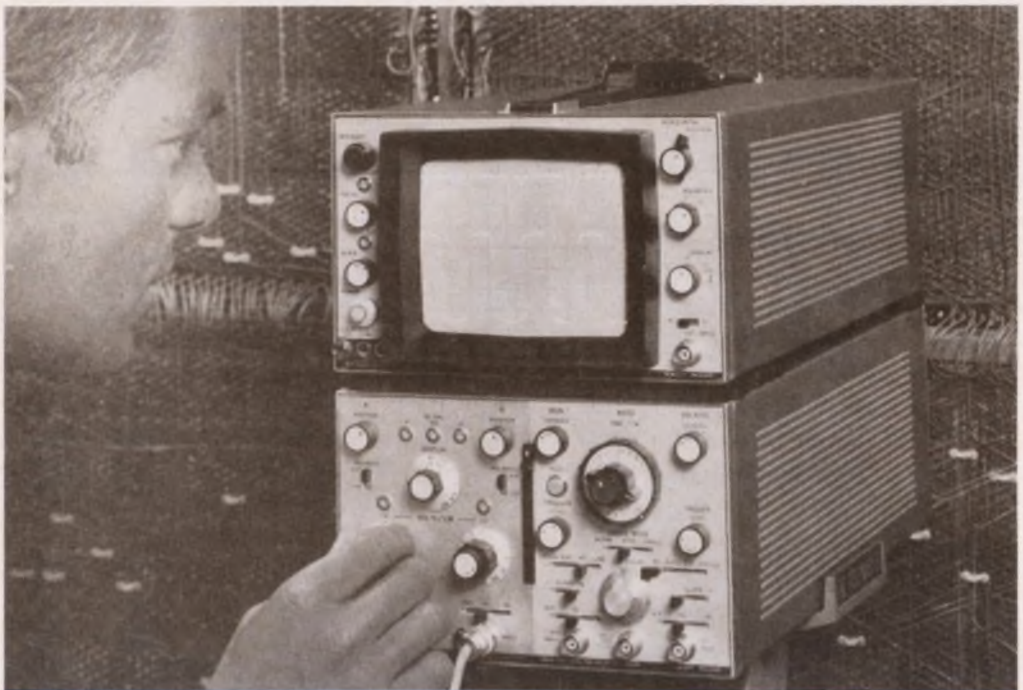
Need Sigma relays fast? Call your Sigma distributor for off-the-shelf delivery of our most popular types.

ON READER-SERVICE CARD CIRCLE 18



NEW hp 180A OSCILLOSCOPE

You can *see more, do more* with this 30-pound oscilloscope that goes anywhere—field, laboratory, or production line. Designed from the user's viewpoint in, this new dual-trace 50 MHz scope is packed with new ideas and innovations to give you big picture CRT, plug-in versatility, step-ahead all-solid-state performance, minimum weight and rugged design. These features add up to *more total performance, more usability than any other scope on the market!*

The hp 180A mainframe is the first with power supplies specifically designed for solid-state circuitry—gives you full performance benefits from solid-state devices in all present and future plug-ins. With hp's all-new big-picture 8 x 10 cm CRT, you have an extra-large display area —get bigger displays, make accurate measurements easier!

Vertical amplifiers drive the CRT vertical deflection plates directly, allowing even greater bandwidth capabilities in future plug-ins. Vertical amplifiers have low drift FET input stages for accurate DC measurements . . . plus quick 15-second warm-up. Time base plug-ins offer new easy to use delayed sweep for examining complex waveforms in detail. Tunnel diode triggering circuits lock in waveforms to 90 MHz. Exclusive hp mixed sweep feature combines display of first portion of trace at normal sweep speeds, and simultaneously expands trailing portion of trace at faster delayed sweep speed to allow magnified examination.

See the back of the actual size color photo at the right for abbreviated specifications and price. For full specifications and a demonstration of how you can *see more, do more* with this new, versatile, go-anywhere scope, call your nearest hp field representative. Or, write to Hewlett-Packard, Palo Alto, California, 94304. Tel. (415) 326-7000; Europe: 54 Route des Acacias, Geneva.

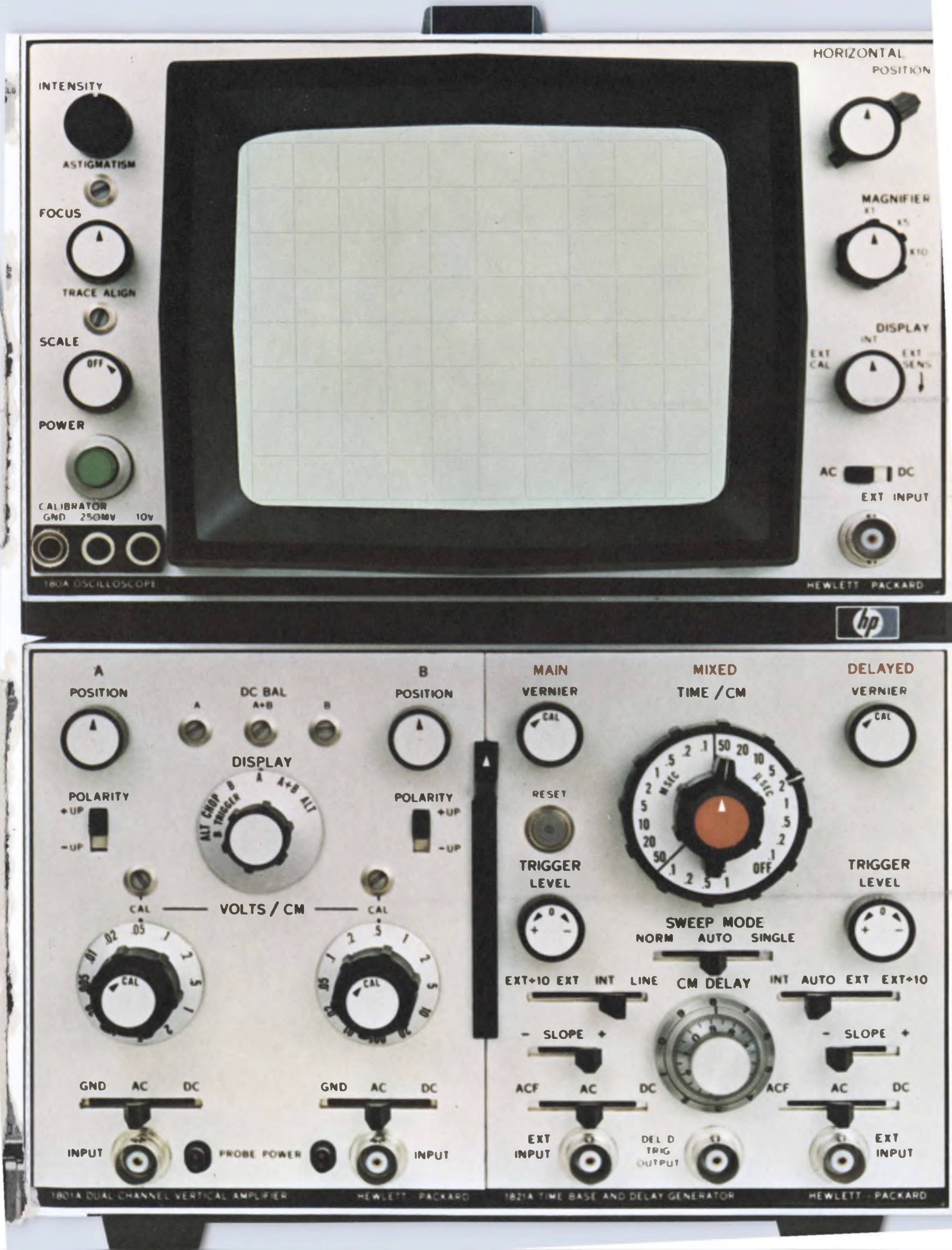
HEWLETT hp PACKARD

An extra measure of performance

SEE MORE! DO MORE!

Tear out actual photo of 180A Oscilloscope. Set it on your bench. See what the big picture display will mean to your work.

ON READER-SERVICE CARD CIRCLE 19


INTENSITY
ASTIGMATISM
FOCUS
TRACE ALIGN
SCALE
OFF
POWER
CALIBRATOR
GND 250MV 10V
180A OSCILLOSCOPE
HORIZONTAL
POSITION
MAGNIFIER
X1 X5 X10
DISPLAY
INT
EXT CAL
EXT SENS
AC DC
EXT INPUT
HEWLETT PACKARD
A
POSITION
DC BAL
A A+B B
B
POSITION
DISPLAY
A A+B ALT
POLARITY
+UP
-UP
POLARITY
+UP
-UP
CAL
VOLTS / CM
CAL
GND AC DC
GND AC DC
INPUT
PROBE POWER
INPUT
1801A DUAL CHANNEL VERTICAL AMPLIFIER
HEWLETT · PACKARD
MAIN
MIXED
DELAYED
VERNIER
TIME / CM
VERNIER
RESET
TRIGGER
LEVEL
TRIGGER
LEVEL
SWEEP MODE
NORM AUTO SINGLE
EXT÷10 EXT INT LINE
CM DELAY
INT AUTO EXT EXT÷10
- SLOPE +
- SLOPE +
ACF AC DC
ACF AC DC
EXT
INPUT
DEL'D
TRIG
OUTPUT
EXT
INPUT
1821A TIME BASE AND DELAY GENERATOR
HEWLETT · PACKARD

hp 180A Oscilloscope

is shown here ACTUAL SIZE:

COMPARE DISPLAY!

See how the new 180A Big Picture Display can make it easier for you to get accurate measurements. Punch out this actual size CRT area on the perforations. Place the punched-out portion over the screen of your existing high-frequency scope. You will find the hp 180A Oscilloscope has 30% to 100% larger viewing area for easier-to-see, easier-to-read traces!

COMPARE SPECIFICATIONS! (Condensed)

180A Oscilloscope

Horizontal Amplifier:

External Input: DC coupled, dc to 5 MHz; AC coupled, 5 Hz to 5 MHz. Input RC, 1 megohm shunted by approximately 30 pf.

Sweep Magnifier: X1, X5, X10; magnified sweep accuracy ±5%.

Calibrator: 1 kHz square wave, 250 mv and 10 v p-p, ±1%.

Cathode-ray Tube: 8 x 10 cm parallax-free internal graticule marked in centimeter squares. Post-accelerator tube, 12 kv accelerating potential; aluminized P31 phosphor.

Beam Finder: Pressing Beam Finder control brings trace on CRT screen.

Intensity Modulation: Approx. +2 volts, dc to 15 MHz, will blank trace.

Active Components: All solid state, except CRT.

Environment: 180A scope with plug-ins operates within specs over the following ranges. Temperature: −28°C to +65°C. Humidity: To 95% relative humidity to 40°C. Altitude: To 15,000 ft. Vibration: Vibrated in three planes for 15 min. each with 0.010" excursion from 10 to 55 Hz.

Power: 115 or 230 volts, ±10%, 50-1000 Hz, 95 watts, convection cooled.

Dimensions: Cabinet, overall dimensions with feet and handle: 8" x 11" x 22½" deep. Rack mount: 5¼" x 19" x 19½" deep behind front panel.

Weight: With plug-ins, net 30 pounds.

Outputs: Main and delayed gates, main and delayed sweeps.

Accessories Furnished: Two 10:1 voltage divider probes, mesh contrast filter.

Price: Without plug-ins, Model 180A, $825.00; Model 180AR (rack), $900.00.

1801A Dual Channel Vertical Amplifier

Modes of Operation: Chan. A alone; Chan. B alone; Chan. A and B displayed on alternate sweeps; Chan. A and B displayed by switching at 400 kHz rate, with blanking during switching; Chan. A plus Chan. B (algebraic addition).

Deflection Factor (Sensitivity): 0.005 v/cm to 20 v/cm; attenuator accuracy, ±3%.

Bandwidth and Rise Time: DC coupled, dc to 50 MHz; AC coupled, 2Hz to 50MHz; rise time, <7 nsec.

Input RC: 1 megohm shunted by approx. 25 pf.

Polarity Presentation: + or − Up.

Triggering: Provides sufficient signal to the time base to trigger from dc to 50 MHz.

Price: Model 1801A, $650.00.

1820A Time Base

Sweep Range: 24 ranges, 0.05 μsec/cm to 2 sec/cm in a 1,2,5 sequence; accuracy, ±3%; to 5 nsec/cm with X10 magnifier. Also single sweep.

Triggering:

Internal: See vertical amplifier.

External: dc to 50 MHz from signals 0.5 v p-p, 90 MHz with 1 v p-p.

Automatic: Bright base line displayed in absence of input signal. Triggers from 40 Hz to > 50 MHz.

Trigger point and slope: Controls allow selection of level and pos. or neg. slope; trigger level on external signal adjustable ±5 v, ±50 v in ÷ 10 position.

Coupling: AC, DC, ACF.

Variable Holdoff: Permits variation of time between sweeps to allow triggering on asymmetrical pulse trains.

Price: Model 1820A, $475.00.

1821A Time Base and Delay Generator

Main Sweep: 22 ranges, 0.1μsec/cm to 1 sec/cm in 1,2,5 sequence; accuracy, ±3%; to 10 nsec/cm with X10 magnifier. Also single sweep.

Triggering:

Internal: See vertical amplifier. External: dc to 50 MHz from signals 0.5 v p-p, 90 MHz with 1 v p-p.

Automatic: Bright base line displayed in absence of an input signal. Triggers from 40 Hz to > 50 MHz.

Trigger point and slope: Controls allow selection of level and pos. and neg. slope; trigger level on external signal adjustable ±5 v, ±50 v in ÷ 10 position.

Coupling: AC, DC, ACF.

Trace Intensification: Used for setting up delayed or mixed sweep. Increases in brightness that part of main sweep to be expanded full screen in delayed sweep or made magnified part of display in mixed sweep.

Delayed Sweep: Delayed time base sweeps after time delay set by main sweep and delay controls. 18 ranges, 0.1μsec/cm to 50 msec/cm in 1,2,5 sequence; accuracy, ±3%.

Triggering: Applied to intensified Main, Delayed, and Mixed Sweep modes. Automatic: Delayed sweep starts at end of delayed period. Internal, External, Slope, Level, and Coupling: same as Main Sweep.

Delay Time: (before start of delayed sweep): Continuously variable from 0.1 μsec to 10 sec; accuracy, ±1%; linearity, ±0.2%; time jitter, <0.005% of maximum delay of each range.

Trigger Output: (at end of delay time): approx. 1.5 v pulse.

Mixed Sweep: Dual sweep display in which main sweep drives first portion of display and delayed sweep completes display at speeds up to 1000 times faster.

Price: Model 1821A, $800.00.

HEWLETT hp PACKARD

An extra measure of quality

Light pen to mask via computer

Using a computer, a TV-like display screen, and a "light pen" to draw images on the screen, IBM engineers have significantly reduced the time between a design idea and a finished scale drawing of a microcircuit.

Instantaneous communication between engineer and computerized display does away with many tedious steps associated with circuit design and creation of an engineering drawing: the computer turns a light pen drawing into a finished circuit mask. Thus, intermediate drawings, which must be redrafted when the engineer modifies his design, can be eliminated. Engineers using the display screen and light-sensitive pen can change their designs simply by manipulating the computer-generated images of transistors, diodes, resistors and other components.

When the design is in final form, a computer-controlled printer produces a precise, scale-drawn layout of the circuit. This hard-copy drawing is then photographically reduced to make a printing mask. The mask is used in actual printed-circuit fabrication.

IBM has also experimented at its East Fishkill, N. Y., facility with computer-assisted logic design, using the display screen to map out logic blocks representing computer functions. By repositioning the

Computer-aided computer design—with a computer-controlled graphic display and light-pen. Final hard-copy drawing is used to make mask for actual fabrication.

blocks, the engineer modifies the computer's operating scheme. The designer can then question the computer to determine how to interconnect components to perform the desired logic operation.

According to IBM engineers, the technique could be applied to large-scale integration, where the objective is to create many computer circuits within a single chip of silicon. Computerized design could minimize interconnections within and among circuits on the chip to achieve maximum circuit use without increasing the size of the unit. The work was described at the 1966 Fall Joint Computer Conference in San Francisco. ■ ■

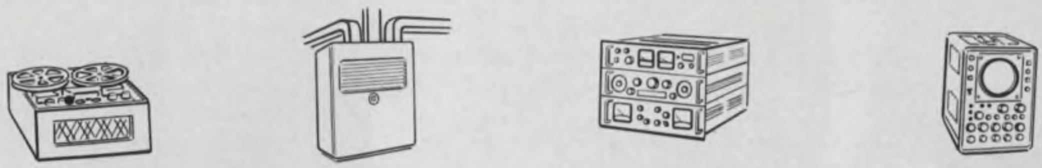
Airport visibility measured by laser

A laser technique reported to offer the first practical means of measuring visibility along aircraft glidepaths is now under study by the Federal Aviation Agency.

The new method being developed at the Sperry Rand Research Center, Sudbury, Mass., uses a photomultiplier receiver to analyze the "signature" of the light scattered back by the atmosphere from a pulsed-ruby laser beam.

The technique uses a 10-MW, *Q*-switched laser and an optical receiver, mounted with their axes parallel and separated by from one to six feet. The laser transmits a 20-ns pulse, which is scattered and absorbed by dust or water vapor particles along its path. In smoke, haze, or fog, the more numerous particles scatter more light back to the receiver.

The receiver converts the returned light into an analog electrical signal, which is then viewed on an oscilloscope. The displayed trace shows the back-scattered energy as an increasing, peaking, and exponentially decaying curve. ■ ■



works when airflow stops!

UNIQUE APPROACH TO AIR FLOW SENSING OFFERS POSITIVE PROTECTION... *it's from G-V*

The G-V Air Flow Sensing Switch uses a new design concept and technique in monitoring the presence of air flow. The device utilizes a thermal principle which eliminates all moving parts, allows operation in any plane and eliminates maintenance and sensitive adjustments. It features a built-in time lag to disregard brief transient interruptions. It operates an alarm or automatic shut-down if the air flow drops below a safe level in electronic equipment, cooling packages, air conditioners, computers and wherever an air-flow cooling system is used. Military versions and mountings for industrial equipment are available.

G-V

G-V CONTROLS INC.
LIVINGSTON, NEW JERSEY 07039
(201) 992-6200

ON READER-SERVICE CARD CIRCLE 91

SEALED ELECTRICAL THERMOSTATS

Cartridge Type: Series C8 hermetically sealed and still adjustable. Contact rating up to 5 amps. **Crystal Can Size:** Series VE-2 hermetically sealed. Contact rating up to 3 amps. **Features:** Rapid rate of response; minimal differential; operating range, —65° to +300°F; vibration to 2000 Hz; shock to 50g.

G-V

ON READER-SERVICE CARD CIRCLE 95

SOLID STATE TIME DELAY

Series 900-064 has been accepted as a standard for many military and aerospace applications where high quality, reliability and cost are requirements. **Features:** hermetically sealed; fixed or adjustable time delays 0.1 to 60 sec,; solid state or relay output; vibration to 2000 Hz; shock, 50g.

G-V

ON READER-SERVICE CARD CIRCLE 96

DIRECT-LINE FIELD ENGINEERING SERVICE

G-V assistance is always available to help you design and produce a better product. G-V Regional Field Engineers in your area will assist you and your design group in new applications and proper selection of your controls. G-V Product Engineers will help you with special applications. When you require experience, products and services in electro-mechanical and solid-state controls . . . call your man from G-V.

G-V

ON READER-SERVICE CARD CIRCLE 97

Laser system counts railroad freight cars

Counting the cars in an ordinary freight train, as any rural youngster knows, is a tedious job —and one that is subject to human error. But supposing you were asked to count—and identify—every car in a busy railroad yard . . . ?

Westinghouse has come up with a simple solution: a laser system that detects and identifies the railroad cars at the entrance and exit to the yard. The system, installed beside the tracks, provides a continuous inventory of cars in the yard. It is fast enough to pick out and identify the cars as they travel at any speed up to 80 mph. The Association of American Railroads will begin testing the method on the Pennsylvania Railroad this month.

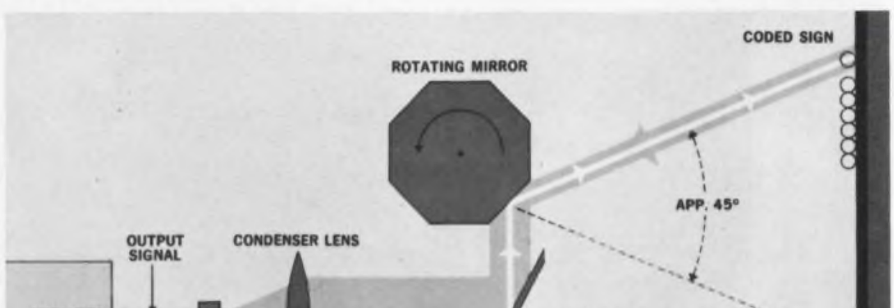
The system uses a 300-milliwatt helium-neon gas laser. Its output is directed through a small hole in a fixed mirror, reflected off a rotating mirror and onto a binary-coded sign attached to the side of a passing railroad car.

The binary-coded light from the sign is reflected off the rotating and fixed mirrors, through a condenser lens and onto the lens of a photo field-effect transistor. The output of the FET is amplified, checked to ensure its validity and used to operate any standard punch or printer, or it can be used as a computer input.

The six-inch-wide car signs are made from retroreflective tape and coded into five-level binary numbers or letters with 10 characters per sign. The tape is similar to that used on auto bumpers and some highway signs. Two tape widths are used, one to represent the binary zero and the other the binary one.

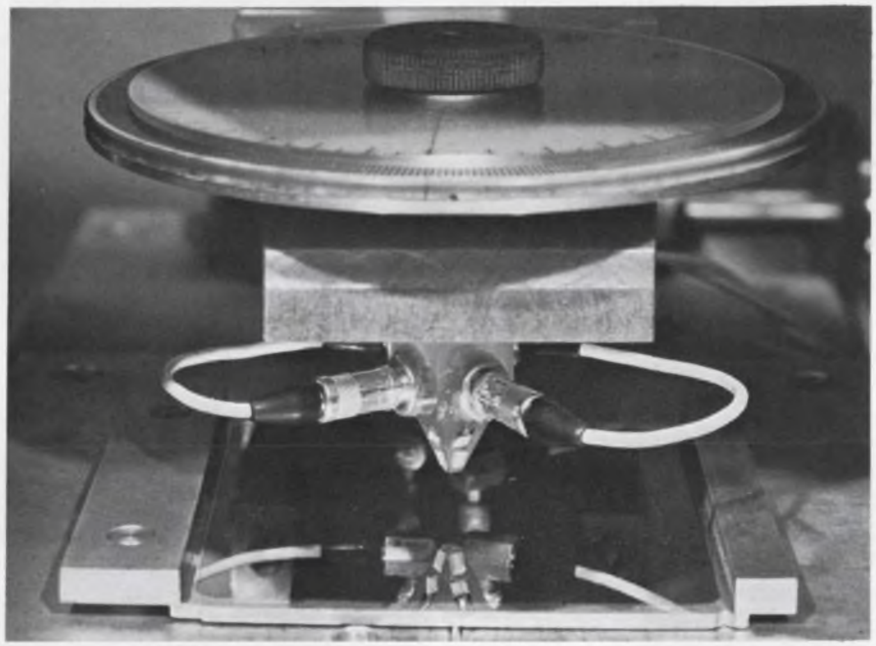
The retroreflective nature of the tape causes the reflected light to follow the same path as the projected beam. A slight divergence of the reflected light does occur, however, and is important for proper system operation. The divergence allows the returned light to reflect off the fixed mirror rather than enter the small hole through which the laser beam was first projected.

The first system built used an eight-sided rotating mirror, but the system to be tested will have a 15-sided mirror, a Westinghouse spokesman said. The rotating mirror provides a vertical scanning arc of 45° to 90° depending on how far the system is located from the tracks. The system can scan a sign that is traveling past at 80 mph at least 4 times; however, only two scans are required to check the validity of returned binary information. ■ ■



Laser beam reads signs on the side of box cars by focusing the binary-coded reflected light onto a photo field-effect transistor. The transistor output is amplified and fed into a computer or printer.

Microprobe checks tiny magnetic domains



The microprobe can be rotated to test H-B relationships in any direction.

Some companies have a serious interest in evaluating the suitability of experimental magnetic films for computer memories. But the estimate of a film's ability to store information at extremely high density requires the testing of mil-sized areas at high resolution.

IBM has devised a tester that makes just such measurements. It consists of a special probe, a 10-MHz signal generator, a 20-MHz tuned amplifier and an oscilloscope. The probe is simply a nonconductive needle around which are wrapped two fine wires.

One wire is connected to the signal generator and transmits a 10-MHz magnetic field to the surface of the magnetic film under test. The other wire is the receiver: its turns convert the oscillating magnetic field of the film into a voltage. The tuned receiver amplifies the second harmonic of the sensing coil. (It filters out the fundamental, because if it did not, the transmitting coil would merely resonate with the receiving coil and there would be no interaction at all with the magnetic film.) The unit tests the film by displaying the imposed field, H, on an axis perpendicular to the sensed field, B. This provides information about the film's saturation point and hysteresis.

The unit can even analyze magnetic films coated with oxides, metals and other nonmagnetic materials. Tests can also be performed in arbitrary magnetic fields produced by a pair of Helmholtz coils.

One square inch of magnetic film may contain 10,000 bit positions or more. These films, typically 4 microinches thick, are made by plating a nonmagnetic substrate with a magnetic alloy.

Most measurement techniques now use optical methods which require bulky equipment and special darkrooms. ■ ■


POWER
SAMPLING RATE
OVERLOAD
RATIO
VOLTS
OHMS
FAIRCHILD
INTEGRATING DIGITAL METER MODEL 7100A
Another
FAIRCHILD
precision instrument
made with
silicon Planar
solid state
devices

Ultrasonics check on pressure leaks

A new three-pound ultrasonic leak detector will accompany each production F-111 to its tactical base. With it, a technician can accurately check out the integrity of the pressurized electronic and radar systems up to ten times faster than if he used soap solutions, according to General Dynamics' Aerospace Ground Equipment Group.

It is extremely important to spot leaks immediately, as the aircraft's several radar systems are kept under pressure by a single air source.

The tester, built by the Delcon Div. of Hewlett-Packard Co., Palo Alto, Calif., consists of an ultrasonic microphone responding to 36—44 kHz, a frequency shifter that makes ultrasonic sounds audible, and a pair of earphones. So equipped, the operator can "hear" ultrasonic sounds emanating from pinhole leaks. Since the microphone is insensitive to sounds that are ordinarily audible, the earphoned operator is not distracted by the usual hissing and buzzing sounds of an operating aircraft.

In the past, mechanics have made such tests by crawling into barely accessible spaces, liberally spreading soapy water on joints and crevices, and watching for little soap bubbles. The process could take days to check one aircraft thoroughly. ■ ■

As the microphone nears a leak, an audible hiss gets louder. The leak detector also has a meter and volume control.

RCA announces 40429 and 40430 6A TRIACS

- With high gate sensitivity
- With symmetrical triggering characteristics (I_{GT}=25 mA max)
- With surge current protection up to 80A
- and the price on the 40429 is only............ $1.50*

RCA 40429 controls 720 watts at 120 volts (V_{BOM} = 200 V). *$1.50 each in quantities of 1,000 and up.

RCA 40430 controls 1440 watts at 240 volts (V_{BOM} = 400 V). $1.98 each in quantities of 1,000 and up.

RCA brings you a new generation of control devices! Each of these 6-amp Triacs can provide the same full-wave function as *two* SCRs...with the option of using either positive *or* negative gate-trigger signals. Hermetically sealed in an all-welded TO-66 package, RCA 40429 and 40430 can simplify your control circuits...reduce costs...add reliability and efficiency.

Evaluate these new RCA Triacs for AC motor controls, heat controls, universal motors, dc power supplies, or solenoid or relay controls. They could very well be the key to next year's model improvements.

For complete information including price and delivery, contact your RCA Field Representative. For technical data, write RCA Electronic Components and Devices, Commercial Engineering, Section RG12-1, Harrison, N. J. 07029.

CHECK YOUR RCA DISTRIBUTOR FOR HIS PRICE AND DELIVERY

GATE FIRING CHARACTERISTICS

Quadrant	I +		I −		III +		III −	
mA @ 25°C	typ.	max.	typ.	max.	typ.	max.	typ.	max.
	10	25	20	25	20	25	10	25

RCA ELECTRONIC COMPONENTS AND DEVICES

The Most Trusted Name in Electronics

Laser system helps delay RF and microwave signals

A continuously variable delay line that operates on signals in the RF and microwave ranges has been successfully tested at United Aircraft Research Laboratories, Norwalk, Conn. A laser beam interacts with an acoustical wave to provide delays up to 10 μs at 1 GzH and 500 μs at 30 MHz.

The delay system should find its greatest use in radars, information processing and electronic countermeasures, according to its developers, Drs. Mike J. Brienza, research physicist, and Anthony J. DeMaria, principal scientist.

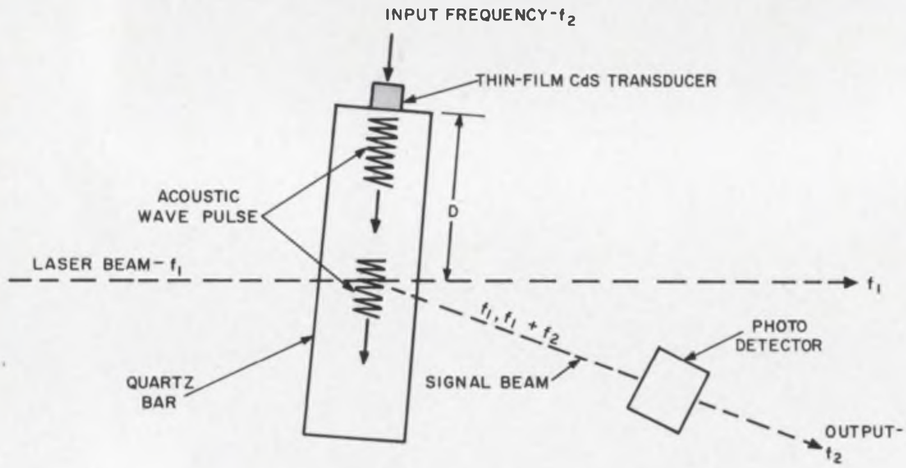
Essentially, the system consists of a laser beam, an acoustic delay medium and a photodetector (see figure). The input to the acoustic medium, through a thin-film cadmium sulfide transducer, is the signal to be delayed, at the frequency *f2*. The time needed for the generated acoustical wave to propagate down to the point where the laser beam enters the rod determines the delay. This time depends on the distance, *D*

The delay may be varied continuously by changing the location of the intercept point. This is done either by changing the direction of the laser beam or by moving the rod.

The interaction of the laser beam and the acoustical wave results in a frequency shift (by *f2*) of the output light beam. Optical heterodyning with the aid of a photodetector (pin in this case) recovers the delayed signal.

The acoustical material depends on the frequency range, says De Maria: "The ideal material is lithium niobate. It is small and can operate continuously from 30 MHz up to 2 GHz with delays from 0 to 10 μs. However, the material is quite unreliable now. At room temperature, we use fused quartz up to about 60 MHz and crystalline quartz up to about 800 MHz."

The bandwidth depends on the transit time of the acoustical wave. A typical value is about 19 MHz at 500 MHz. Better focusing of the laser improves the bandwidth by decreasing the transit time. ■ ■



Laser beam interacts with acoustical wave to provide continuously adjustable delay for RF and microwave signals. The delay depends on the distance D.

New technique seals thousands of semiconductors at once

A new sealing technique which will make it possible to encapsulate thousands of silicon semiconductor devices while they are still on a single silicon wafer has been reported by scientists at Bell Telephone Laboratories, Murray Hill, N. J.

The seal is formed by application of a layer of silicon nitride and beam lead contacts to the silicon dioxide layer of the transistor and integrated circuit device.

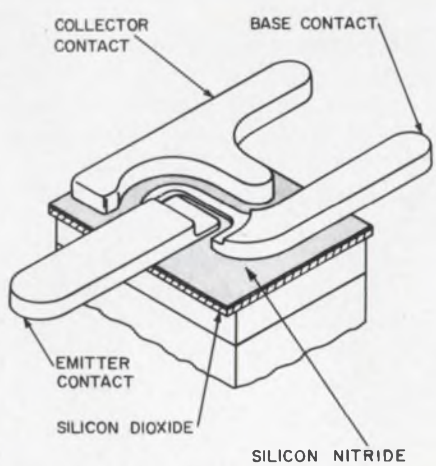
With standard encapsulation methods, the silicon slice must be cut into individual circuits and each circuit encapsulated separately—usually in vacuum-tight metal cans for high-reliability devices.

Deposition of the silicon nitride layer is accomplished by mixing two gases, silicon hydride (diluted in hydrogen) and ammonia, near a heated silicon slice. The silicon nitride adheres to the slice to form a protective barrier against penetration of sodium and other metallic ions. Beam lead contacts, are then applied to the device.

The contacts form a strong mechanical bond with the silicon nitride layer, thus sealing the required contact areas against ion penetration and preventing the leads from becoming detached.

The completed wafer is finally etched apart. The individual devices and circuits are impervious to acids that would ruin canned devices, and can withstand accelerations of 300,000 G.

"Actually we have yet to see a failure due to shock," says the inventor of the process Martin Lepselter, "but our centrifuges don't go any higher." ■ ■



New junction seal shown on epitaxial silicon transistor.

Letters

SQUID magnetometer's sensitivity questioned

Sir:

Your source of information about magnetometer state of the art ["Sensitive SQUID measures minute magnetism," ED 17, July 19, 1966, pp. 35-37] must be confused. There are several instruments commercially available that can measure magnetic fields in the order of 10^{-8} gauss. There are at least 100 magnetic observatories around the world that continuously monitor the "tiny fluctuations in the earth's magnetic field." The term usually used in geophysical work is a gamma, which is 10^{-5} gauss. We are presently working with microgamma units several orders of magnitude below the SQUID sensitivity.

Your statement about measuring from zero to 50 microgauss is extremely misleading since 50 microgauss is a rather large unit and there are no units that can measure zero field intensity.

The major problem with magnetic measurements using sensitive instruments is caused by the ambient magnetic noise. I doubt seriously that any measurements were made on the SQUID or any other instrument at the levels you indicate. It takes special techniques to get these environmental levels controlled well enough to permit measurements.

Our standard magnetometers have 10-milligamma sensitivity. We also make special magnetometers for magnetic research with much lower sensitivity. Varian Associates of Palo Alto, Calif., advertise a rubidium magnetometer with 0.002-gamma resolution.

While the SQUID may represent a new technique, it certainly is not a sensitivity breakthrough.

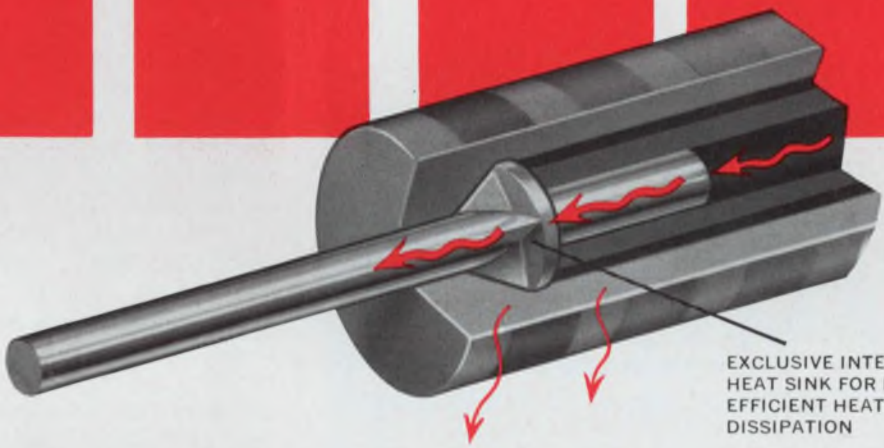
Fred J. Morris
President and Director of Research
The Electro-Mechanics Co.
Austin, Tex.

The authors reply

Sir:

We were most interested to learn that Fred Morris is selling magnetometers of 10^{-8}-gauss sensitivity and that he has developed 10^{-9}-

IRC



Fixed composition resistors offer

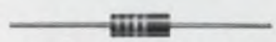
Lower changes at high temperatures

When tested for prolonged periods at high temperatures, IRC fixed composition resistors clearly established their superior high temperature and high overload characteristics.

Even after 1,000 hours at 100°C and full rated power, resistance changes are less than the 10% MIL allowance. After 1,000 hours at 150°C, no load, resistance changes are still well within MIL limits. At 200% rated power at 70°C ambient, resistance changes are less than 10% after hundreds of hours of operation. Resistance temperature coefficient is typically less than 0.064%/°C over the range of 25°C to 150°C.

Here's why. IRC's resistance element is a carbon composition film that is bonded to a glass substrate at approximately 1,000°F. This results in superior high temperature performance. And, IRC's exclusive talon leads go deep into the body and act as heat sinks to conduct heat out of the resistors.

For better load life and long term stability, specify IRC fixed composition resistors. Write for catalog, prices and sample to:
IRC, Inc., 401 North Broad Street, Philadelphia, Pa. 19108.



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- Values to 100,000 megohms

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ON READER-SERVICE CARD CIRCLE 31

gauss sensitivity in special-order units. Accordingly, he is correct in stating that 10^{-7}-gauss in a rubidium-vapor magnetometer is "state of the art."

Members of our staff here in Dearborn, however, have used laboratory versions of the SQUID magnetometer to make scientific studies in which the sensitivity of 10^{-8} gauss was achieved.

In our Cryogenics Devices Dept., which is located in Newport Beach, Calif., we have a research program under way to determine the limiting sensitivity of SQUID magnetometers and we have now developed a system in which the noise level is about 10^{-10} gauss.

Thus it would appear that both the SQUID system and Mr. Morris' variable-mu method have comparable sensitivity in their present state of development. While we agree with him that making measurements with sensitive magnetometers is difficult because of ambient magnetic noise, we have developed elaborate, laboratory-type systems for reducing this noise and the numbers that we provided for the article are based on actual measurements that we have recorded.

Peter B. Spender
Scientific Research Staff
Ford Motor Co.
Dearborn, Mich.

Accuracy is our policy

In the Application Note, "Piezoelectric Accelerometer," ED 25, Nov. 8, 1966, p. 202, two equations were misprinted. In paragraph 4, line 11, the equation should read:

$$F = Ma.$$

The equation three lines below this should read:

$$q = dF = dMa.$$

In "A 35-lb radar set destined for Vietnam," ED 24, Oct. 25, 1966, p. 40, the name of the radar's manufacturer was wrongly stated. It is made by the Radio Receptor Div. of the General Instrument Corp., Hicksville, N. Y.—not by the General Radio Corp.

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a family of high voltage ***60 Amp*** *NPN Silicon Power Planar Transistors featuring* V_{CEO} *ranges from* ***200V to 300V****, capable of* P_T*=350W @ 25°C!*

(ACTUAL SIZE)

Type Number	DESIGN LIMITS				PERFORMANCE SPECIFICATIONS					
	P_T Watts 25°C Case	BV_{CBO} Volts $I_C = 1mA$	$V_{CEO(SUS)}$ Volts $I_C = 0.2A$	BV_{EBO} Volts $I_E = 1mA$	h_{FE} $I_C = 40A$	h_{FE} $I_C = 60A$	V_{BE} (sat) Volts $I_C = 40A$	V_{CE} (sat) Volts $I_B = 6A$	I_{CBO} μA $V_{CB} = 100V$	f_T MH$_z$
	Max.	Min.	Min.	Min.	Min.	Min.	Max.	Max.	Max.	Typ.
SDT8951	350	200	200	8	10-40	5	2.0	2.0	10	20
SDT8952	350	225	225	8	10-40	5	2.0	2.0	10	20
SDT8953	350	250	250	8	10-40	5	2.0	2.0	10	20
SDT8954	350	275	275	8	10-40	5	2.0	2.0	10	20
SDT8955	350	300	300	8	10-40	5	2.0	2.0	10	20

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ON READER-SERVICE CARD CIRCLE 33

EDITORIAL

Who's complaining now. . . and who's listening?

If you are a supervisor or manager, how do you react to a constant griper? Do you dismiss him as a pest who wastes valuable time? Or do you welcome an opportunity to identify, and—hopefully—rectify, an employee's problem?

If you report to an engineering manager, do you feel comfortable about airing your complaints to him? Or are you convinced that you would be wasting your time and possibly jeopardizing your job security?

Grappling with gripers is not an easy battle for several reasons. First, reason and logic often go by the board as tempers rise. Second, the two parties involved both tend to talk and argue—neither seems to listen. And third, both parties may be right, but expressing the same ideas differently.

Here are some tips for the griper:

- Get the facts. Don't quote uninformed sources on such matters as company policy, plant relocation or cutbacks in design projects.
- Organize your complaints. Don't jump from one subject to another. Keep to the main points, and avoid quibbles.
- Be open to suggestions and explanations. It's pointless to relate your opinions and conclusions and then close your ears to the manager's side of the story.

And here's some advice for the manager:

- Listen and listen attentively. Don't miss any facts. Hold off phone calls and other interruptions until the air is cleared.
- Summarize the points made. Show the griper that you have clearly identified his message and allow him the opportunity to correct any misinterpretations.
- Be honest—admit mistakes where they exist. If you indicate action will be taken, make sure action is taken soon. Don't make excuses or shift the blame.
- Clearly explain questions relating to company policy. Use written policy statements whenever possible to add weight to your statements.
- Be human. Listen to the griper and delve a bit into his home situation. Don't pry—but try to determine whether personal problems are disturbing him on the job.

Gripers and managers share one common burden—neither can perform effectively in a hostile environment. And it's not really that difficult to resolve differences intelligently.

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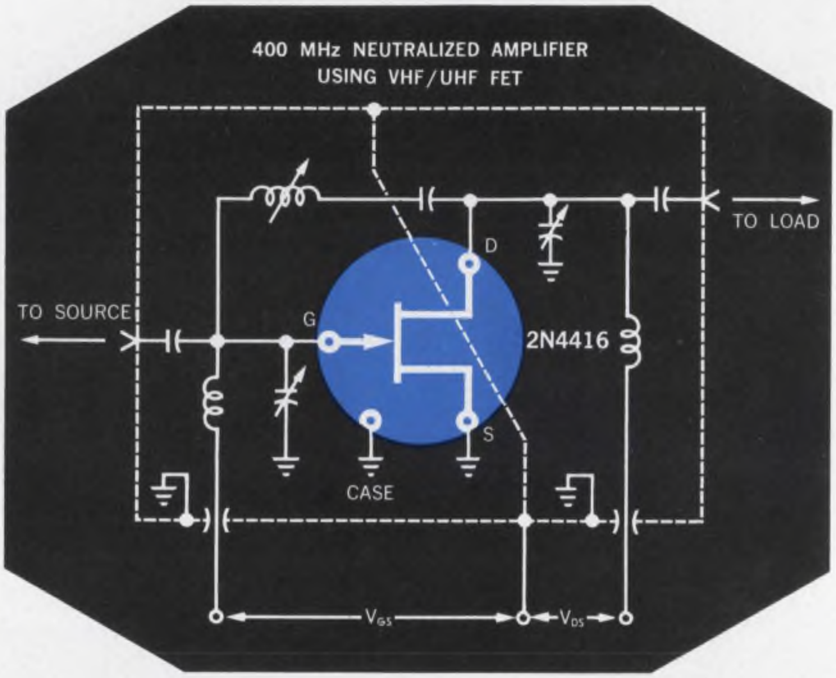
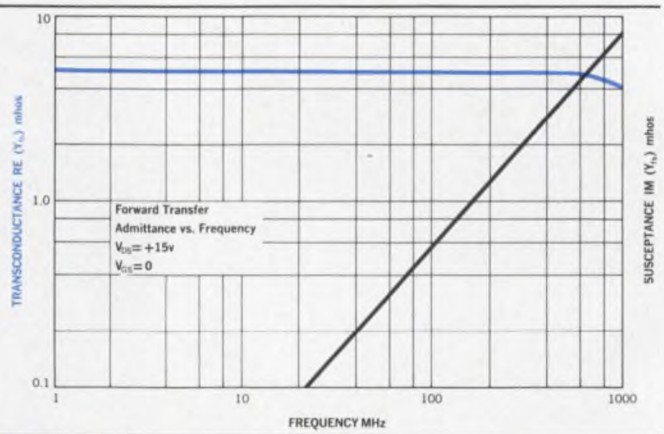
Replace 80% of all FET types with one!



Here's how: Buy the Union Carbide 2N4416 universal FET in quantity, and you can select transistors over the entire frequency range covered by 80% of all field effect types. The 2N4416 is specified below as a VHF/UHF amplifier. However, from any class lot of this device you can select (1) general purpose, low noise, high gain amplifiers from D.C. to 900 MHz, or (2) ultra low noise devices for low frequency applications. This device is also available in a ribbon lead ceramic package (.138" dia.) as the low capacitance 2N4417. Use for TV tuners, FM sets, IF strips, mixers, oscillators, or even switches. Write for complete specifications.

CHARACTERISTICS Small Signal, Common Source @ 25°C	**2N4416 TO–72**	**Frequency**
Forward Transconductance RE (Y_{fs}) (min.)	4000 μmhos	400 MHz
Input Capacitance, C_{iss} (max.)	4.0 pf	1.0 MHz
Output Capacitance, C_{oss} (max.)	2.0 pf	1.0 MHz
Reverse Transfer Capacitance, C_{rss} (max.)	0.8 pf	1.0 MHz
Spot Noise Figure (Neutralized), NF (max.)	4.0 dB	400 MHz
Spot Noise Figure, NF (max.) (Neutralized)	2.0 dB	100 MHz
Power Gain, G_{ps} (min.) (Neutralized)	10.0 dB	400 MHz



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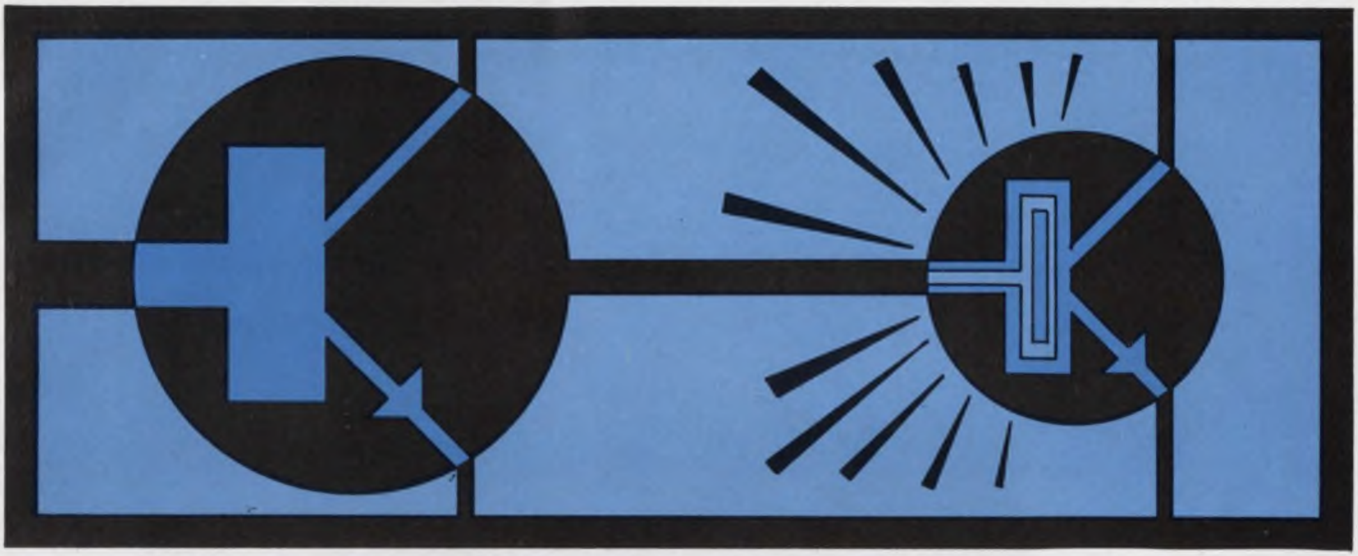
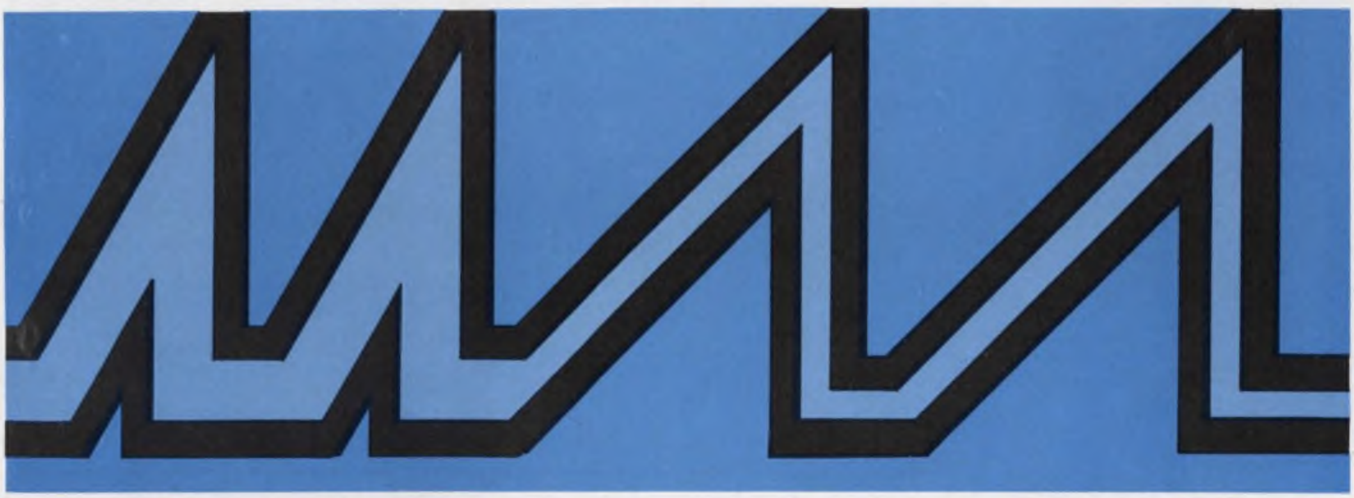
ON READER-SERVICE CARD CIRCLE 35

Technology



The thermal runaway point of transistor audio output stages evaluated by a combination of experiments and computations is found accurately with little effort. Page 54.



Fast ramp generators with ultralinearity and great flexibility in varying slope and amplitude are obtained by charging the timing capacitor from a constant current source. Page 68

Also in this section:

Transistor systems' behavior is given by statistics and random sampling. Page 62

Proper specifications allow the relay manufacurer to give maximum service. Page 76

Correctly applied, low-resistance trimmers offer numerous advantages. Page 82

Cross-referenced index reduces the paperwork on MIL designs. Page 92

Evaluate thermal runaway point

of transistor audio output stages using experimental data and a set of simple calculations.

Determination of the thermal runaway point of a transistor circuit can be difficult and the result may be vague. The approach described below does away with much of the work and many of the sources of error inherent in a pure mathematical calculation. It combines experiments and computations in such a fashion as to arrive at an accurate solution with minimum effort. It applies to a wide variety of circuits that meet several general requirements, which will be defined.

What is thermal runaway?

The basic concept of thermal runaway is the following: as ambient temperature increases, it causes a rise in the junction temperature of a transistor. The higher junction temperature causes an increase in transistor dissipation, and this, in turn, results in a change in temperature rise between junction and ambient.

The total effect can be compared to a closed-loop system which is stable only for certain values of loop gain. When the loop gain is less than unity (i.e., if the increase in temperature rise is less than the induced change), even though the junction temperature increases more than the ambient temperature, a stable point is reached.

Experimental analysis for transfer curve

To determine whether the loop gain is high enough to initiate runaway, two factors must be known:

- The rate of change of dissipation with respect to junction temperature.
- The change in temperature rise which results from a given change in dissipation.

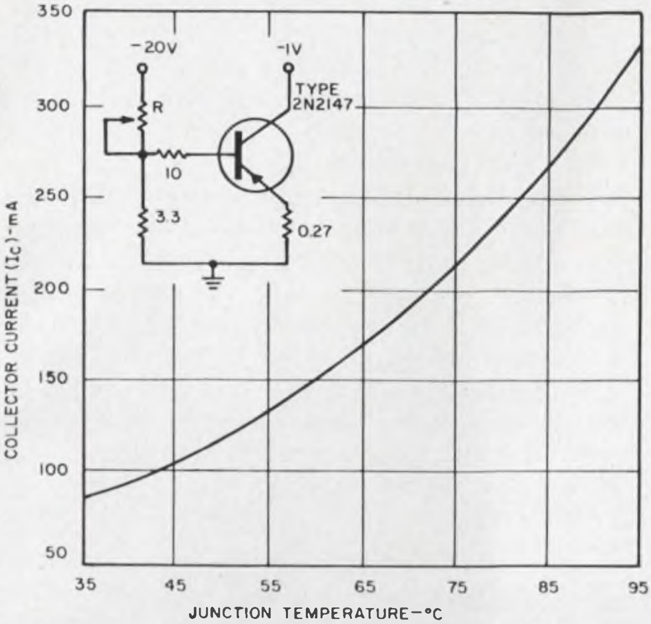
The second factor can easily be determined as the product of the increase in power dissipation, P_C, and the thermal resistance, Φ. Under dc conditions, the first factor can be determined from the collector-to-emitter voltage (assumed constant in an output stage where dc resistance is negligible) and the transfer characteristic between collector current and junction temperature. This transfer characteristic is a function of the circuit configuration, component values and device parameters (such as common-emitter current transfer ratio, β, collector-cutoff current, I_{CO}, base-to-emitter voltage, V_{BE}, and others).

The difficult and imprecise part of the analysis occurs when an attempt is made to develop this transfer characteristic from theory. The transfer characteristic can, however, be determined experimentally, if the circuit under consideration is

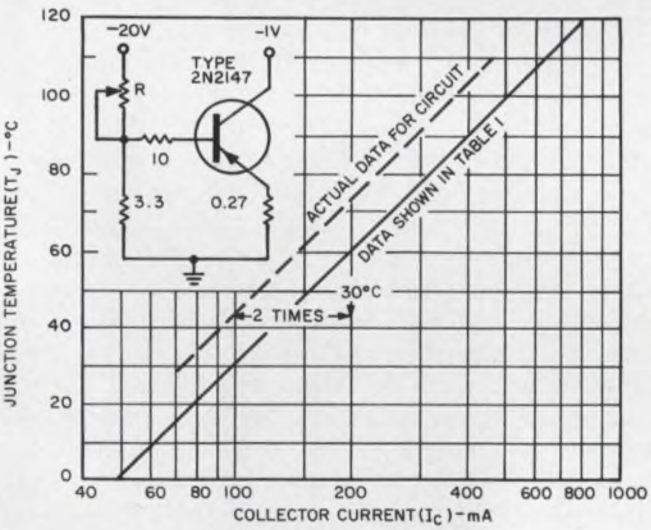
M. S. Fisher, Applications Engineer, RCA, Harrison, N. J.

Glossary of terms

- Φ – thermal resistance
- $\Phi_{J-\infty}$ – thermal resistance between the junction and infinity
- β – common-emitter forward current transfer ratio
- P_C – collector power dissipation
- P – maximum non-regenerative dissipation at high signal levels
- I_C – collector current
- I_0 – collector idling current
- I_{CO} – collector cutoff current
- V_{BE} – base-to-emitter voltage
- V_{CE} – collector-to-emitter voltage
- D – degrees required to double I_C
- T_C – case temperature
- T_J – junction temperature
- T_∞ – temperature at infinity point
- $T_{J-\infty}$ – temperature rise between the junction and infinity
- T_{JR} – junction temperature at which runaway occurs
- T_{RR} – temperature rise at the runaway condition
- T_{AR} – ambient temperature which causes runaway
- $T_{A\,ext}$ – actual external ambient temperature



1. **The collector resistance** of an audio output stage should be small as shown in the above typical output-stage dc bias arrangement. Note the nonlinearity in the collector current vs junction temperature.



2. **Collector current doubles** for every 30°C increase in the junction temperature for this circuit. The transfer characteristic is a pure exponential.

operated at a low collector-to-emitter voltage, V_{CE}, to avoid dissipation, and the case temperature, T_C, is varied (in an oven or heat controller) to provide the desired values of collector current, I_C, as a function of junction temperature, T_J.

Figure 1 shows a transfer characteristic determined experimentally for a typical output-stage dc bias arrangement using a 2N2147 transistor. The curve is plotted on linear co-ordinates to illustrate the nonlinearity of the transfer characteristic. At low junction temperatures, the slope (or change in I_C for a given change in T_J) is small. As junction temperature increases, the slope increases, and thus the loop gain also increases.

When the curve of Fig. 1 is replotted on semilog graph paper, as shown in Fig. 2, it can be seen that the transfer characteristic is a pure exponential over the range of interest. (This relationship exists because of the exponential nature of I_C as a function of V_{BE} and the exponential nature of I_{CO}.) For the curve in Fig. 2, collector current doubles for every 30°C increase in junction temperature.

The junction temperature at which thermal runaway will occur can be determined for dc operating conditions by use of a chart such as that shown in Table 1. For the example shown, collector current I_C is assumed to be 0.1 ampere at a junction temperature of 30°C. The transfer characteristic is assumed to be parallel to that obtained in Fig. 2 (i.e., to have the same slope so that I_C doubles for every change of 30°C in T_J). Data for T_J and I_C are given in Columns 1 and 2, respectively. Column 3 shows the collector dissipation, P_C, which is equal to I_C (from column 2) times the collector-to-emitter voltage, V_{CE} (assumed to be 20 volts in the example). Column 4 shows the temperature rise between the junction and infinity, $T_{J\infty}$, which is equal to the dissipation (from column 3) times the thermal resistance from junction to infinity, $\Phi_{J-\infty}$ (assumed to be 5°C/W). The infinity point is defined as the ambient point at which no temperature change results from a change in dissipation.* Column 5 shows the temperature at the infinity point T_∞, which is equal to T_J (from column 1) minus the temperature rise (from column 4). Column 6 shows the change in T_∞ between a row and its preceding row divided by the corresponding change in T_J. For instance, T_∞ increases by 20°C from row 1 to row 2, while T_J increases by 30°C; therefore, column 6 for row 2 is +20/30.

As junction temperature increases, the increase in T_∞ required to produce a given increase in T_J becomes smaller, because the slope of the transfer characteristic increases with junction temperature (i.e., loop gain increases). By the time row 4 is reached (T_J = 120°C), T_∞ is decreasing for increases in T_J, column 6 is negative, and runaway has occurred. The point at which thermal runaway occurs is the point at which $\Delta T_\infty/\Delta T_J$ in column 6 is zero. For the data shown in Table 1, it can only be determined that this point occurs somewhere between temperatures of 60°C (where $\Delta T_\infty/\Delta T_J$ is positive) and 120°C (where $\Delta T_\infty/\Delta T_J$ is negative). A closer determination can be made by use

*It should be noted that the infinity point is not the ambient in the immediate vicinity of the device, especially if the device is enclosed and the air is still, because the immediate ambient temperature can change as a result of dissipation. A runaway problem can exist when an amplifier is placed in a closed environment because of the high thermal resistance to infinity.

of smaller increments between the rows, or by mathematical analysis.

Mathematical analysis gives runaway point

In order to derive an equation for the junction temperature at which thermal runaway occurs, it is necessary first to derive an expression for the transfer characteristic which was plotted from the experimental data. Such an expression is derived in Appendix 1-A for a pure exponential in terms of D, the number of degrees required to double the current. The current, I_0, at zero junction temperature can be determined by extrapolation of the curve to zero or by solution for I_0 at known values of I_C and T_J. For the data plotted in Fig. 2, the value of D is 30°C and the value of I_0 is 0.05 ampere. Collector current I_C is then given by:

$$I_C = 0.05\,\epsilon^{(0.69)(T_J)/30}. \qquad (1)$$

It should be noted that D is the slope of the exponential curve plotted on semilog paper, as shown in Fig. 2. If D is not a pure exponential (i.e., varies with junction temperature), the value of D is obtained from the slope of the curve at the junction temperature of interest.

As already stated, the point at which runaway occurs can be determined by use of smaller and smaller increments of T_J until the following condition is reached:

$$\lim_{\Delta \to 0} \frac{\Delta T_\infty}{\Delta T_J} = 0 \quad \text{or} \quad \frac{dT_\infty}{dT_J} = 0.$$

When this definition is used for thermal runaway and zero collector resistance is assumed, an expression can be derived for the junction temperature at which thermal runaway occurs, T_{JR}. This expression, which is derived in Appendix 1-B, is as follows:

$$T_{JR} = (D/0.69) \ln [(D/0.69)/I_0\, \Phi_{J-\infty}\, V_{CE}]. \qquad (2)$$

For the data shown in Table 1, the following solution is obtained by use of this equation:

$$T_{JR} = (30/0.69) \ln [(30/0.69)/(0.05)(5)(20)] = 94°\text{C}.$$

Effects of changes in various parameters

Examination of Eq. 2 reveals that idling current I_0, collector-to-emitter voltage V_{CE}, and thermal resistance $\Phi_{J-\infty}$—all have the same effect. Therefore, if the values of two or more of these parameters are changed but the product of the three remains the same, the value of T_{JR} does not change. For example, in a given circuit with fixed values of D and $\Phi_{J-\infty}$, the voltage could be doubled if the idling current were cut in half, and the runaway temperature would not change.

The factor D appears in two places in the numerator. A higher value of D (more junction-temperature change required to double the collector current) results in a higher value of T_{JR}, as would be expected for a circuit with a higher stability factor. However, if a circuit that has a higher value of D is operated near the limit of its thermal-runaway capability, greater variability results from changes in I_0, $\Phi_{J-\infty}$, or V_{CE}. This effect can lead to smaller safety margins for high line voltages, component tolerances, and the like for a circuit that has a better stability factor. Reasons for this effect are discussed below.

Appendix 1-C derives equations (A-15 through A-22) that show the effect on T_{JR} of changes in the various parameters in Eq. 2. These equations are used below to illustrate the effect of changes of a factor of two from the original condition:

If the value of D is doubled, the new value of T_{JR} is given by:

$$T_{JR_2} = 2(T_{JR_1} + D_1). \qquad (3)$$

That is, T_{JR} increases more than twice.

If the product $I_0\, \Phi_{J-\infty}\, V_{CE}$ is doubled (by changes in any or all of the three parameters), the new value of T_{JR} is given by:

$$T_{JR_2} = T_{JR_1} - D. \qquad (4)$$

That is, a change by a factor of two in $I_0\, \Phi_{J-\infty}\, V_{CE}$ (possibly as the result of a change of $2^{1/3} = 1.26$ in each parameter) decreases T_{JR} by D°C.

As an example, it is assumed that two circuits have similar T_{JR} values of 100°C, but different D values of 30°C and 60°C (the latter circuit must have a higher $I_0\, \Phi_{J-\infty}\, V_{CE}$ product to provide a T_{JR} of 100°C). In either circuit the $I_0\, \Phi_{J-\infty}\, V_{CE}$ product could change by a factor of two as a result of supply-voltage variations or a change in thermal resistance resulting from transistor tolerances, improper connection to the heat sink, or location of the circuit in a crowded environment.

Because the value of T_{JR} decreases by D degrees in either case, in the circuit where D was originally 30°C the value of T_{JR} becomes 70°C. In the "more stable" circuit where D is 60°C, however, T_{JR} is reduced to 40°C. This example illustrates the fact that a circuit cannot be judged for stability by the D factor alone. Only a complete analysis in terms of thermal runaway under worst-case conditions reveals the actual safety margin.

(It will be shown later that, of the two circuits in the example, the one that has the higher value of D will also "run away" at a lower ambient temperature. This result emphasizes that the analyses must be carried to a solution for ambient temperature before a true evaluation of the thermal capability is achieved.)

Dc conditions for thermal runaway

Appendix 1-D shows how T_{JR} can be eliminated from the equations to provide an expression for

Chart for determining thermal runaway point

(I_C = 0.1 A at T_J = 30°C; Φ = 5°C/W; V_{CE} = 20 V)

	Column 1 Junction Temperature T_J—°C	Column 2 DC collector current I_C—A	Column 3 DC collector dissipation P_C—W	Column 4 Temperature rise $T_{J-\infty}$—°C	Column 5 Temperature at infinity T_∞—°C	Column 6 $\Delta T_\infty/\Delta T_J$
Row 0	0	0.05	1	5	−5	——
Row 1	30	0.1	2	10	20	+25/30
Row 2	60	0.2	4	20	40	+20/30
Row 3	90	0.4	8	40	50	+10/30
Row 4	120	0.8	16	80	40	−10/30

the operating conditions at the point where thermal runaway occurs. Eq. A-26 demonstrates that the point of thermal runaway is reached for the following conditions:

$$\Phi_{J-\infty} I_C V_{CE} = T_{RR} = D/0.69. \qquad (5)$$

In other words, thermal runaway occurs if the temperature rise due to direct current and voltage equals the $D/0.69$ factor. It should be noted, however, that the collector current, I_C, in this equation is the value obtained when the junction temperature has increased to T_{JR}.

It may take some time, even hours, for the temperature (and thus the collector current) to rise to this value and for runaway to occur. It is desirable, then, to determine what dc conditions must exist at the time of initial turn-on to cause eventual increase of the junction temperature to T_{JR}, and thus to cause runaway. Appendix 1-E derives this condition with the assumption that there is no temperature rise at the first instant (because of the thermal capacitance) so that the junction temperature is equal to the ambient temperature. The result shows that the initial ($t = 0$) dc conditions required to cause eventual thermal runaway (when there is no change in ambient temperature) are given by:

$$\begin{aligned} V_{CE} I_{C(t=0)} &= D/(0.69)(\epsilon)(\Phi_{J-\infty}) \\ &= D/(0.69)(2.72)(\Phi_{J-\infty}). \end{aligned} \qquad (6)$$

It should be emphasized that this expression cannot be used if the ambient temperature changes. It can be used only if the dc conditions at time zero are measured at the maximum expected ambient temperature. Even under these conditions, the expression does not give an indication of the safety margin in terms of changes in the ambient temperature.

The ambient temperature which produces thermal runaway under dc conditions, T_{AR}, can be determined by combining Eqs. 2 and 5:

$$T_{AR} = T_{JR} - D/0.69. \qquad (7)$$

This ambient temperature, T_{AR}, is of most concern to the circuit designer. Equation 7 shows that T_{AR} is lower than T_{JR} by $D/0.69$ degrees under dc conditions.

Ac conditions are obtained from dc analysis

Although only dc operating conditions have been considered thus far, the results of the dc analysis can also be used to analyze an audio output stage that develops ac power.

As mentioned previously, thermal runaway, in its fundamental form, is a closed-loop phenomenon in which an induced change in junction temperature causes a change in dissipation, which causes a change in temperature rise which, in turn, causes a further change in junction temperature.

Under dc conditions, the change in dissipation is the result of a change in the dc collector current caused by the increased junction temperature. When an ac signal is present, there is no collector current, but there is still a change in dissipation. This is a result of the change in the operating load line which results from a changed junction temperature. Just as the rate of change of collector dissipation with respect to junction temperature under ac conditions differs from that under dc conditions, so too the temperature at which runaway occurs is different. In both Class-A and Class-AB operation, however, the worst-case conditions occur during dc (idling) conditions. Hence, both Table 1 and Eqs. 1 through 7 can still be used.

In a Class-A output stage, dissipation is always highest when there is no ac power output. For this dc condition, therefore, the equations may be applied directly. For experimental verification, a Class-A output stage should be checked out by increasing the ambient temperature while the output stage is idling.

Equation 4 shows that T_{JR} decreases by D°C when the product $I_0 \Phi_{J-\infty} V_{CE}$ is increased by a factor of two. Under dc conditions, this lower junction temperature reduces the idling current to half the original value (because current doubles every D degrees), with the net result that the temperature rise at the new value of T_{JR} remains the same (see Eq. 5). In a Class-A amplifier, therefore, a decrease of D degrees in T_{JR} causes a decrease of D degrees in T_{AR}, the ambient temperature required to cause thermal runaway.

In a two-transistor Class-AB push-pull output stage, two factors make the analysis more complex. First, maximum dissipation occurs at decreasing signal levels as idling current increases toward Class-A push-pull. Second, the rate of change of dissipation with respect to junction temperature at high signal levels is very low. (These relationships can be demonstrated by drawing the different load lines that occur at different idling currents and performing the integrations necessary to find average power.)

Two cases must be considered for the two-transistor AB stage. In the first case, operation is such that, when the junction is near T_{JR}, maximum dissipation occurs at high signal level (because of low initial idling current). In this case, the value of T_{JR} calculated from dc considerations may be exceeded as a result of the dissipation at high signal levels; yet runaway will not occur, because the dissipation is less regenerative. However, if the signal is cut off and operation returns to dc while the junction temperature is higher than T_{JR}, thermal runaway will then occur. In other words, thermal runaway can be made to occur if the ambient temperature is increased, some power is dissipated at high signal levels to heat the junction above T_{JR}, and the signal is then cut off to return the stage to dc conditions.

In the second case, operation is such that, when the junction is near T_{JR}, maximum dissipation occurs during idling (because of high idling current). In this case, maximum temperature rise occurs during idling and operation is as for the Class-A stage. Therefore, runaway is made to occur simply by increasing the ambient temperature.

In either case, runaway occurs at the dc condition, and Table 1 or Eq. 2 may be used to determine T_{JR}. In the first case, however, the effective ambient temperature (which is the ambient temperature listed in Table 1) is much greater than the actual ambient temperature because of the temperature rise caused by the nonregenerative dissipation. The actual external ambient temperature $T_{A\,(ext)}$ is determined as follows:

$$T_{A\,(ext)} = T_{JR} - P\Phi_{J\text{-}x}, \qquad (8)$$

where P is the nonregenerative maximum dissipation at the high signal level.

Because operation of a Class-AB stage may be as described for either case, experimental verification involves the following tests. First, the ambient temperature is increased in steps. At each step, temperature is brought to equilibrium provided runaway does not occur. Next, the signal level is varied to determine the signal which causes the highest dissipation (the signal level required may change slightly as heat-sink temperature changes). If temperature equilibrium is obtained, the signal is then cut off and the idling current is observed for a decrease (stable) or an increase (unstable).

In either of the two cases described, when T_{JR} is decreased by D degrees as a result of increasing the product $I_0\,\Phi_{J\text{-}x}\,V_{CE}$ by a factor of two (as in Eq. 4), the external ambient temperature required to reach T_{JR} also decreases by D degrees. In the first case, Eq. 8 shows that T_A must change by the same number of degrees as T_{JR} because $P\Phi_{J\text{-}x}$ is a constant. In the second case, the analysis is the same as for the Class-A stage because dc conditions exist.

Appendix 2 shows sample calculations for the various conditions described.

As a final comment it must be noted that the table and equations developed in this article describe thermal runaway under dc conditions. The table can be used even if collector resistance is present. The equations, however, are valid only for zero collector resistance. In either case, the concept described can be applied to an entire system analysis because the results are based on an experimental D factor for the system rather than a set of equations describing the system. The use of this D factor makes the analysis accurate and practical.

Appendix 1—Derivation of Equations

A. *Required*—To derive an expression for collector current as a function of junction temperature from experimental data.

Procedure—Assume that the data show that the equation is a pure exponential function in which current increases by a certain ratio every time junction temperature increases by a certain increment. Arbitrarily select a ratio of two for current, and determine the increment of junction temperature that corresponds to a doubling of current. The expression can be written:

$$I_C = A\,\epsilon^{xT_J/D}, \qquad \text{(A-1)}$$

where x/D is a constant that provides the required slope of two for every temperature increment D. The value of x necessary for the expression to double in value for an increment of D degrees is determined:

$$\epsilon^{x(T_J+D)/D} = 2\,\epsilon^{xT_J/D}. \qquad \text{(A-2)}$$

When the natural logarithm is taken of both sides of Eq. A-2, the following relation is obtained:

$$\ln \epsilon^{x(T_J+D)/D} = \ln 2\,\epsilon^{xT_J/D}. \qquad \text{(A-3)}$$

This equation can be simplified as follows:*

$$x(T_J + D)/D = \ln 2 + xT_J/D. \quad \text{(A-4)}$$

The value of x is then given by

$$x = \ln 2 = 0.69. \quad \text{(A-5)}$$

When $T_J = 0$, the exponential ϵ^0 is unity and $I_C = A$. However, I_0 is defined as the current when $T_J = 0$. Therefore, $A = I_0$. The final equation can then be written as follows:

$$I_C = I_0\, \epsilon^{(0.69)(T_J)/D}. \quad \text{(A-6)}$$

B. *Required*—To derive an equation describing the junction temperature at which thermal runaway will occur.

Procedure—Assume that there is negligible resistance in the collector-to-emitter circuit and that collector current I_C is a function of junction temperature T_J, as described by Eq. A-6. Collector power P_C then becomes:

$$P_C = V_{CE} I_C = V_{CE} I_0\, \epsilon^{(0.69)(T_J)/D}. \quad \text{(A-7)}$$

If infinity is defined as the point nearest to the junction at which the temperature does not change as a result of dissipation, then temperature rise T_R between the junction and infinity is given by:

$$T_R = \Phi_{J\text{-}\infty} V_{CE} I_0\, \epsilon^{(0.69)(T_J)/D}. \quad \text{(A-8)}$$

The junction temperature, T_J, is given by:

$$T_J = T_R + T_\infty, \quad \text{(A-9)}$$

where T_∞ is the temperature at infinity.

Equation A-8 can be substituted into Eq. A-9:

$$T_J = \Phi_{J\text{-}\infty} V_{CE} I_0\, \epsilon^{(0.69)(T_J)/D} + T_\infty. \quad \text{(A-10)}$$

Equation A-10 can then be rearranged in the form:

$$T_\infty = T_J - \Phi_{J\text{-}\infty} V_{CE} I_0\, \epsilon^{(0.69)(T_J)/D}. \quad \text{(A-11)}$$

Thermal runaway has been defined as occurring when $dT_\infty/dT_J = 0$. Therefore, Eq. A-11 is differentiated to obtain the expression:

$$\frac{dT_\infty}{dT_J} = 1 - \frac{\Phi_{J\text{-}\infty} V_{CE} I_0 (0.69)}{D} \epsilon^{(0.69)(T_J)/D}. \quad \text{(A-12)}$$

This expression is then set equal to zero to obtain the T_J required for runaway, T_{JR}:

$$[I_0 \Phi_{J\text{-}\infty} V_{CE} (0.69)/D]\, \epsilon^{(0.69)(T_J)/D} = 1; \quad \text{(A-13)}$$

$$T_{JR} = (D/0.69) \ln [(D/0.69)/(I_0 \Phi_{J\text{-}\infty} V_{CE})]. \quad \text{(A-14)}$$

C. *Required*—To show the effect of changes in parameters by a given ratio, N.

Procedure—Let the original condition be indicated by the subscript 1 and the new condition by the subscript 2.

(a) Changes in D. The original condition is given by:

$$T_{JR_1} = (D_1/0.69) \ln [(D_1/0.69)/(I_0 \Phi_{J\text{-}\infty} V_{CE})]. \quad \text{(A-15)}$$

If the value of D is changed to $D_2 = ND_1$, Eq. A-15 becomes:

$$\begin{aligned} T_{JR_2} &= (D_2/0.69)\ln[(D_2/0.69)/(I_0 \Phi_{J\text{-}\infty} V_{CE})] \\ &= (ND_1/0.69)\ln[(ND_1/0.69)/ \\ &\quad (I_0 \Phi_{J\text{-}\infty} V_{CE})]. \end{aligned} \quad \text{(A-16)}$$

Equation A-16 can be rewritten in the following forms:

$$\begin{aligned} T_{JR_2} &= (ND_1/0.69)\ln[(D_1/0.69)/ \\ &\quad (I_0 \Phi_{J\text{-}\infty} V_{CE})] + (ND_1/0.69)\ln N; \end{aligned} \quad \text{(A-17)}$$

or

$$T_{JR_2} = N[T_{JR_1} + (D_1/0.69) \ln N]. \quad \text{(A-18)}$$

(b) Changes in the product $I_0 \Phi_{J\text{-}\infty} V_{CE}$. The original condition is given by:

$$T_{JR_1} = (D/0.69)\ln[(D/0.69)/(I_0 \Phi_{J\text{-}\infty} V_{CE})_1]. \quad \text{(A-19)}$$

If the value of $I_0 \Phi_{J\text{-}\infty} V_{CE}$ is changed to $(I_0 \Phi_{J\text{-}\infty} V_{CE})_2 = N(I_0 \Phi_{J\text{-}\infty} V_{CE})_1$, Eq. A-19 becomes:

$$\begin{aligned} T_{JR_2} &= (D/0.69)\ln[(D/0.69)/(I_0 \Phi_{J\text{-}\infty} V_{CE})_2] \\ &= (D/0.69) \ln \{(D/0.69)/ \\ &\quad [N(I_0 \Phi_{J\text{-}\infty} V_{CE})_1]\}. \end{aligned} \quad \text{(A-20)}$$

Equation A-20 can be rewritten in the forms:

$$\begin{aligned} T_{JR_2} &= (D/0.69) \ln [(D/0.69)/(I_0 \Phi_{J\text{-}\infty} V_{CE})_1] \\ &\quad - (D/0.69) \ln N; \end{aligned} \quad \text{(A-21)}$$

or:

$$T_{JR_2} = T_{JR_1} - (D/0.69) \ln N. \quad \text{(A-22)}$$

D *Required*—To eliminate T_{JR} from the equations.

Procedure—If the transistor is biased to the steady-state current which causes runaway (I_{CR}), then the junction temperature is at T_{JR} and Eq. A-6 may be written:

$$I_{CR} = I_0\, \epsilon^{(T_{JR})(0.69)/D}. \quad \text{(A-23)}$$

Equation A-23 can then be solved for T_{JR}:

$$T_{JR} = (D/0.69) \ln (I_{CR}/I_0) \quad \text{(A-24)}$$

Because Eqs. A-14 and A-24 are both expressions for T_{JR}, they may be equated to obtain:

$$\begin{aligned} &(D/0.69) \ln [(D/0.69)/(I_0 \Phi_{J\text{-}\infty} V_{CE})] \\ &\quad = (D/0.69) \ln (I_{CR}/I_0). \end{aligned} \quad \text{(A-25)}$$

If the $D/0.69$ and I_0 terms are canceled and the logarithm is removed from each side, Eq. A-25 can be solved for $\Phi_{J\text{-}\infty} V_{CE} I_{CR}$:

$$\Phi_{J\text{-}\infty} V_{CE} I_{CR} = D/0.69. \quad \text{(A-26)}$$

Equation A-26 shows that the product $I_{CR} \Phi_{J\text{-}\infty} V_{CE}$, which is the temperature rise at the runaway condition, is given by:

$$T_{RR} = D/0.69. \quad \text{(A-27)}$$

E. *Required*—To find, for a constant am-

*$\ln AB = \ln A + \ln B$.

bient temperature, the current at time zero (with T_J assumed equal to T_A) which will provide the final steady-state current (at junction temperature T_{JR}) necessary to cause thermal runaway.

Procedure—At time zero, the junction temperature T_J is lower than the junction temperature for runaway T_{JR} by an amount equal to the temperature rise T_{RR} which occurs when the collector current reaches I_{CR}. The value of T_{RR} is given by Eq. A-27. The collector current I_C at time zero can be written in the following forms:

$$\underset{(t=0)}{I_C} = I_0\,\epsilon^{(T_{JR}-D/0.69)(0.69/D)}; \qquad \text{(A-28)}$$

or

$$\underset{(t=0)}{I_C} = [I_0\,\epsilon^{(0.69)(T_{JR})/D}]/\epsilon. \qquad \text{(A-29)}$$

Equation A-23 can then be solved for I_0 and the result substituted in Eq. A-29:

$$\underset{(t=0)}{I_C} = I_{CR}/\epsilon = I_{CR}/2.72. \qquad \text{(A-30)}$$

Equation A-30 can then be substituted into A-26 to obtain the following relation:

$$\underset{(t=0)}{V_{CE}\,I_C} = D/(0.69)(2.72)(\Phi_{J\text{-}x}). \qquad \text{(A-31)}$$

Appendix 2—Sample problems

A. *Required*—To determine the value of T_{JR} from the data given in Table 1.

Procedure—T_{JR} is calculated from Eq. 2:

$$T_{JR} = (30/0.69)\ \ln\ (30/0.69)/(0.05)(5)(20) = 94°\text{C}.$$

B. *Required*—To determine the value of T_{AR} for the data given in Table 1 under dc conditions.

Procedure—T_{AR} is calculated from Eq. 7:

$$T_{AR} = 94°\text{C} - (30/0.69) = 50.5°\text{C}.$$

C. *Required*—To determine the value of T_{AR} for the data given in Table 1 for a Class-A output stage or a Class-AB output stage in which dissipation during idling at T_{JR} is greater than the fixed dissipation at high signal level.

Procedure—T_{AR} is calculated from Eq. 7:

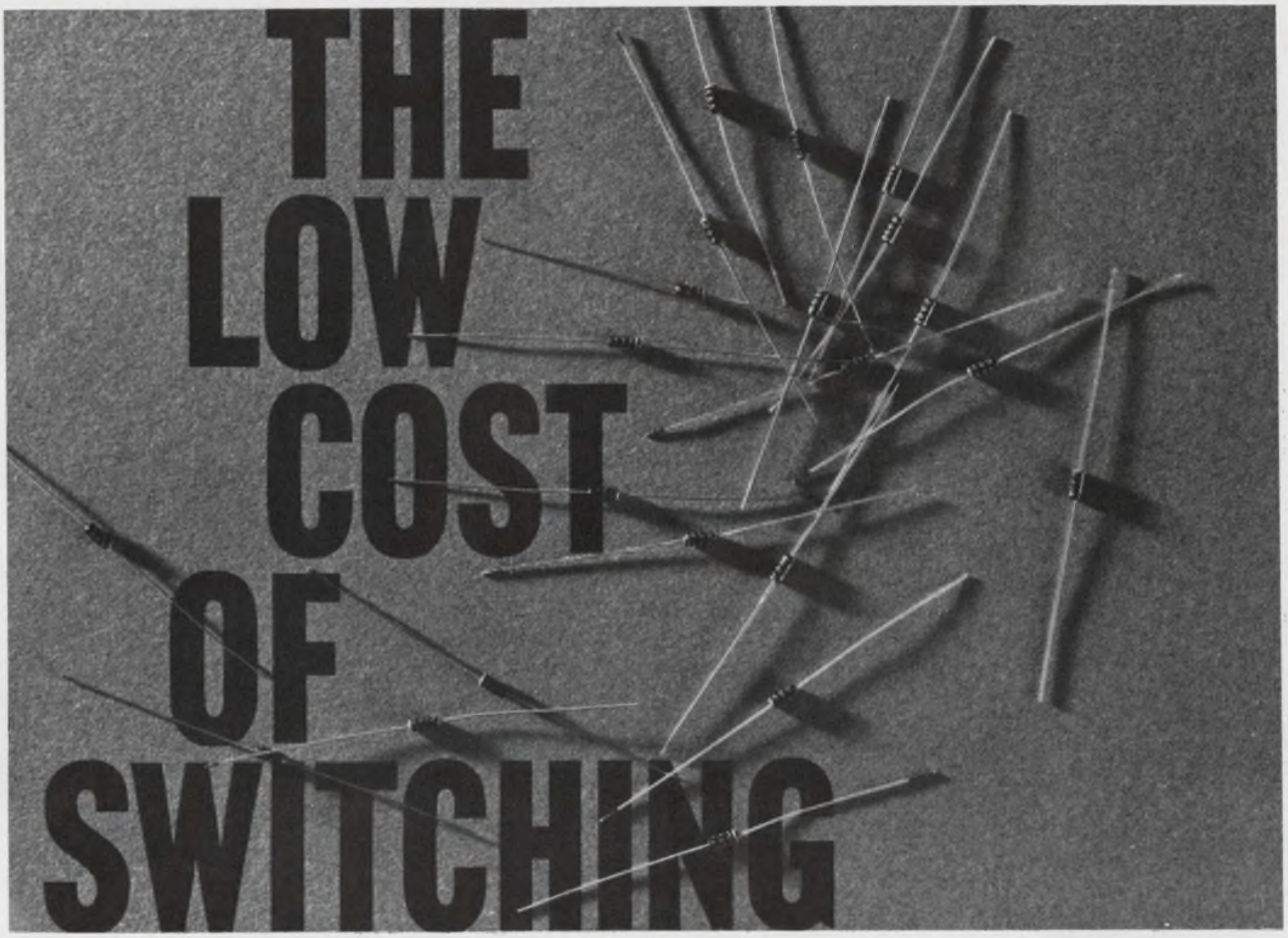
$$T_{AR} = 94°\text{C} - (30/0.69) = 50.5°\text{C}.$$

D. *Required*—To determine the value of T_{AR} for the data given in Table 1 for a Class-AB output stage in which there is a fixed dissipation at high signal level which is greater at T_{JR} than the dissipation during idling.

Procedure—Let the fixed power P equal 10 watts. T_{AR} is then calculated from Eq. 8:

$$T_{AR} = 94°\text{C} - (5)(10) = 44°\text{C}.$$

In this case, runaway will occur when the junction temperature reaches 94°C and signal is then cut off. ■ ■



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Statistics and random sampling will give an accurate picture of a transmission system's behavior.

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In the design of channels that are to process random or almost random signals, stimulation/response tests with single-frequency sine waves may yield deceptive or incomplete measures of system performance. Equal-probability signals and wide-band Gaussian noise are the logical choice as test signals for a statistical examination of system performance.

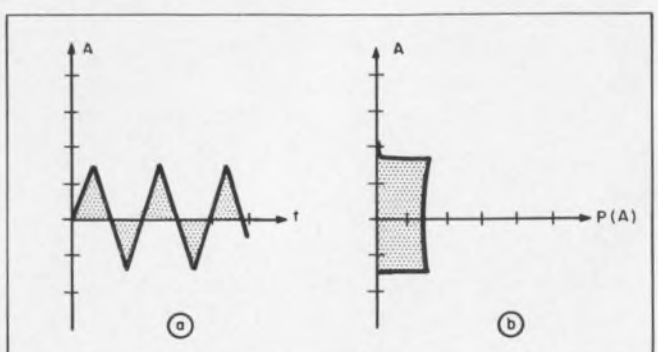
In the statistical description of periodic signals, the amplitude probability density distribution must be carefully related to the actual waveform, since there is an infinite number of waveforms that can exhibit the same density distribution. The probability density distribution function is a measure of the likelihood of finding a waveform at any particular point within a wave's peak-to-peak amplitude excursion. For the periodic signal this function takes a form which is proportional to the inverse of the slope of the waveform.

As an example, consider the triangular wave, a waveform which has the characteristic of being equiprobable. A recording of the actual function (the triangle) and its density distribution is shown in Fig. 1. The statistical description plotted on the left has been rotated 90° clockwise to show the relationship between the probability density distribution and the real-time function. The vertical axes in both plots represent waveform amplitude. The probability density is represented horizontally in the recording on the left. Another example of a time function and its density distribution is shown in Fig. 2. The signal shown is random noise and its distribution is the familiar normal, or Gaussian, curve. In fact, Gaussian noise takes its name from this curve.

The obvious curvature of the distribution of Fig. 1b indicates that the triangle in this plot departs somewhat from the ideal. This distortion is less apparent from an examination of the original signal alone (Fig. 1a).

The sensitivity of the density distribution to irregularities in the ideal waveform appears more clearly in Fig. 3, which shows the triangle wave of Fig. 1 after it has been processed by an amplifier exhibiting crossover distortion.

The probability density distribution has certain characteristics which can be identified and related to the signal being analyzed. In the time domain, a complex signal can often be decomposed into two or more simpler signals for analysis and the superposition used to reconstruct the original signal. The summation of two time signals results in the convolution of their respective density functions. For simplicity of illustration, two deterministic signals (i.e., signals whose values are exactly known at every point in time) are



1. **The triangular waveform (a) is an equiprobable signal.** Its probability density function (b) is a measure of the likelihood of finding the waveform at any particular point within a wave's peak-to-peak amplitude range. Note that (b) has been rotated 90° clockwise from its conventional position.

John Boatwright, Engineering Section Manager, Hewlett-Packard Co., Loveland, Colo.

Conventional ac measurement techniques

Probably the most widely used measurement technique that combines acceptable accuracy and reasonable cost is the absolute-average method. Figure A shows a typical arrangement for making an average measurement. The input signal is amplified (or attenuated) and fed to the meter circuit through the diode bridge. For good linearity the amplifier should exhibit low output conductance at all frequencies of interest. Typical performance limits for this technique restrict the bandwidth to some 10 MHz and sensitivities to a few hundred μV full-scale. Absolute-average-measuring instruments are generally calibrated in the rms value of a sine wave and are relatively insensitive to harmonic distortion.

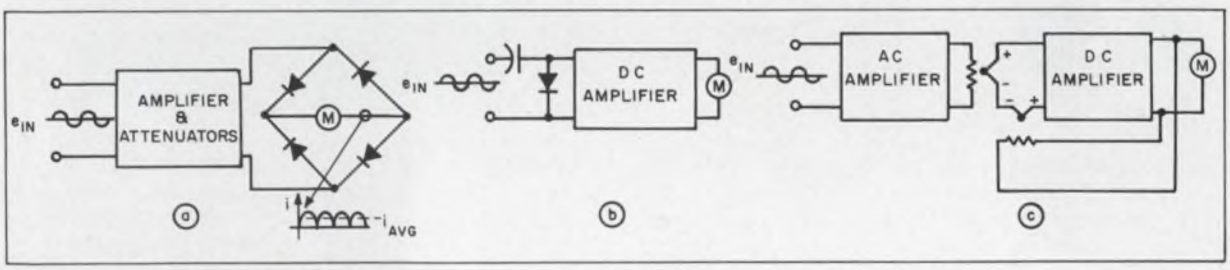
Peak-detecting measuring schemes, one of which is shown in Fig. B, are probably simplest of all and can be performed over a bandwidth extending to several thousand MHz. Good linearity is possible for input sinusoidal signals of one volt and above; for signals smaller than one volt, special compensation techniques must be used to achieve linear read-out. For sinusoidal signals of less than about 30 mV rms, semiconductor diodes will recover the mean square value of the signal being measured rather than the peak value. As in the case of the average-reading instrument, these devices are usually calibrated in the rms value of a sine wave. Peak-reading instruments are generally quite sensitive to harmonic distortion and care must be taken in the interpretation of the measured peak value of a nonsinusoidal waveform.

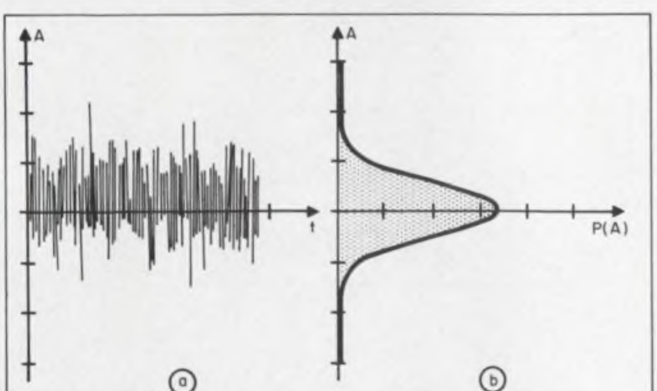
The true rms measurement technique is most often used when a high degree of accuracy is required or when it is necessary to make sensible measurements of nonsinusoidal signals. The block diagram of Fig. C indicates one form of a true rms instrument that makes use of a servo-loop to yield a linear output display.* The thermocouple elements form a bridge which is initially unbalanced by the signal current present in the heater winding in the ac amplifier output. The couple unbalanced is amplified by the dc amplifier and fed back to the heater winding in the second thermocouple, re-establishing bridge balance. The dc current flowing in the one heater winding is then directly proportional to the rms value of the ac signal current in the other winding and may be read out directly on a dc meter.

The performance limitations of this type of instrument are generally imposed by the ac amplifier and are similar to those of the average-measuring instrument mentioned previously. Since the true rms value is measured, independent of the waveshape†, distortion is not an "error-contributing" factor.

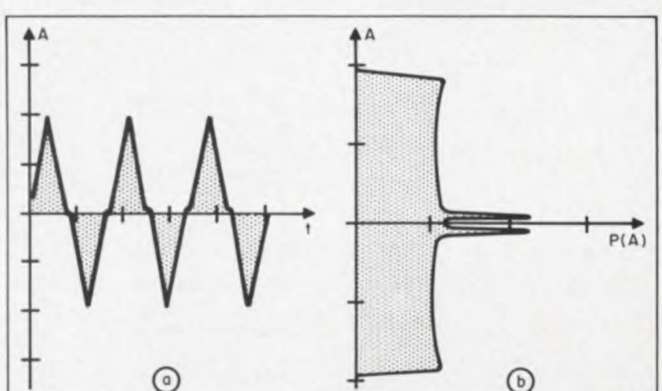
*Arrangement used in Hewlett-Packard Model 3400A rms Voltmeter.

†Provided that peak excursions of the measured waveform do not exceed the dynamic range of the instrument.





2. **Gaussian noise (a) is described statistically** by the familiar normal, or Gaussian, distribution curve (b). It is from this description that Gaussian noise gets its name.



3. **Crossover distortion of the equiprobable triangular waveform** (a) is easier to detect if the signal's density function (b) is examined.

added and the resulting density distribution is shown in Fig. 4. The two signals used are a sine wave and square wave.

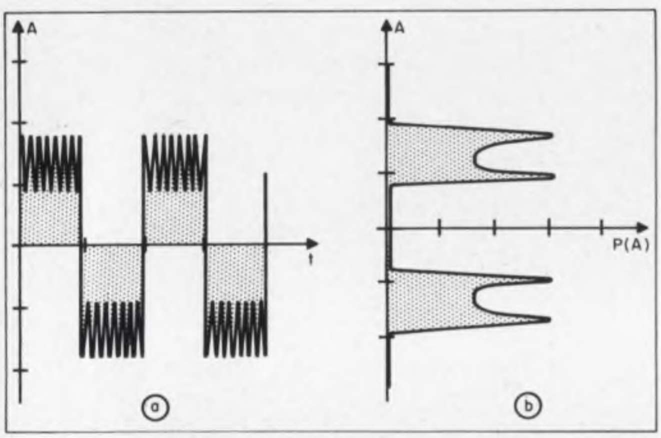
Severe band limiting, either in the processing channel or in the analyzer, will alter the shape of the signal's waveform and will also change the shape of the signal's probability density distribution. Using a test signal such as Gaussian noise is therefore advantageous because the shape of its density distribution is not affected by bandwidth limitation.

Random sampling preserves signal's statistics

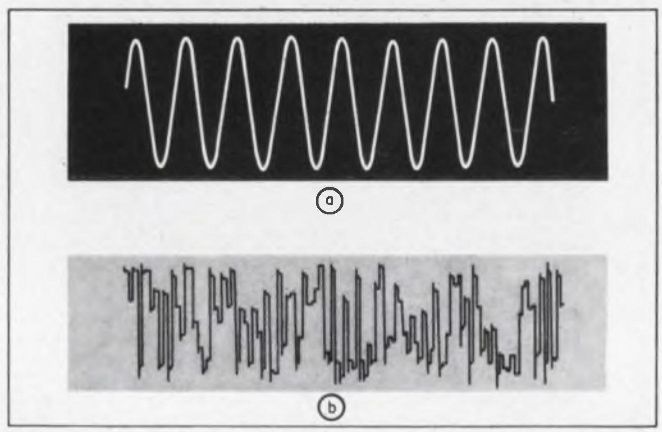
The capability of present equipment is a few megahertz. The usefulness of the statistical approach may be extended beyond this, however, if use is made of recently developed sampling techniques. If the signal to be analyzed is periodic, it is possible to use "synchronized" or coherent sampling actually to reproduce the high-frequency waveform at a much lower frequency—a technique used in the sampling oscilloscope. For purposes of statistical analysis it is not necessary to preserve the actual waveform; therefore the sampler need not be synchronized with the incoming signal. The output of the sampler (retained by a zero-order hold circuit) in this case is a series of pulses of apparently randomly oriented amplitudes. Examination of the process will show that, even though the order of the "stretched" samples bears no coherent relationship to the original signal, the amplitude distribution is identical to that of the wave being measured. That is, although the sampling process is random, the statistics of the signal are preserved.

The upper portion of Fig. 5 shows the original sinusoidal signal which has been randomly sampled. The collection of samples is plotted in the lower trace of the same figure. Note that all time information about the waveshape is lost, but a statistical analysis of each trace would result in the same density distribution.

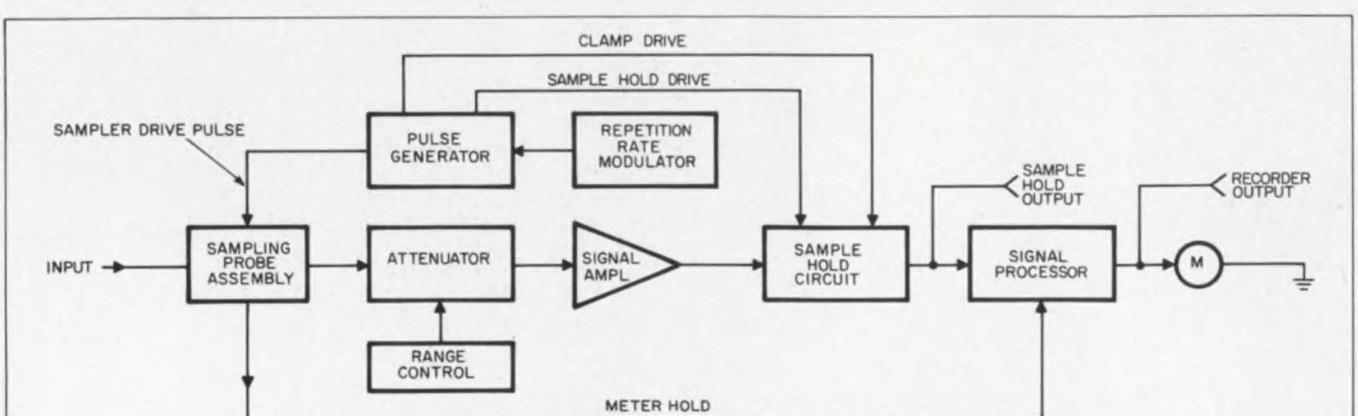
A simplified block diagram of the sampler, the Hewlett-Packard 3406A sampling voltmeter, is shown in Fig. 6. The pulse generator and the sampling bridge in the probe are designed to sample signals which may extend beyond 1000 MHz. The sample is taken in a very short interval; after proper amplification, the value of the sample is



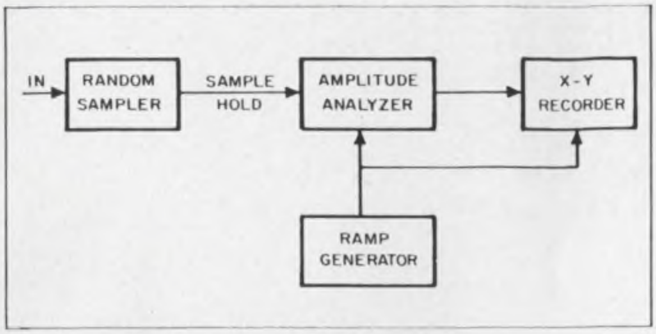
4. **Complex waveforms can often be described** as the sum of two simpler signals in order to simplify analysis. The sum of a sinusoid and a square wave (a) results in the convolution of their respective density functions (b).



5. **Random sampling of a sinusoidal signal** (a) results in the collection of samples shown in (b). All time information about the original waveshape is lost but the probability distribution of both waveforms is identical.



6. **Waveform sampling can be accomplished** by using a sampling voltmeter. A block diagram of an instrument of this type is shown above. Note the relative simplicity of the over-all system.

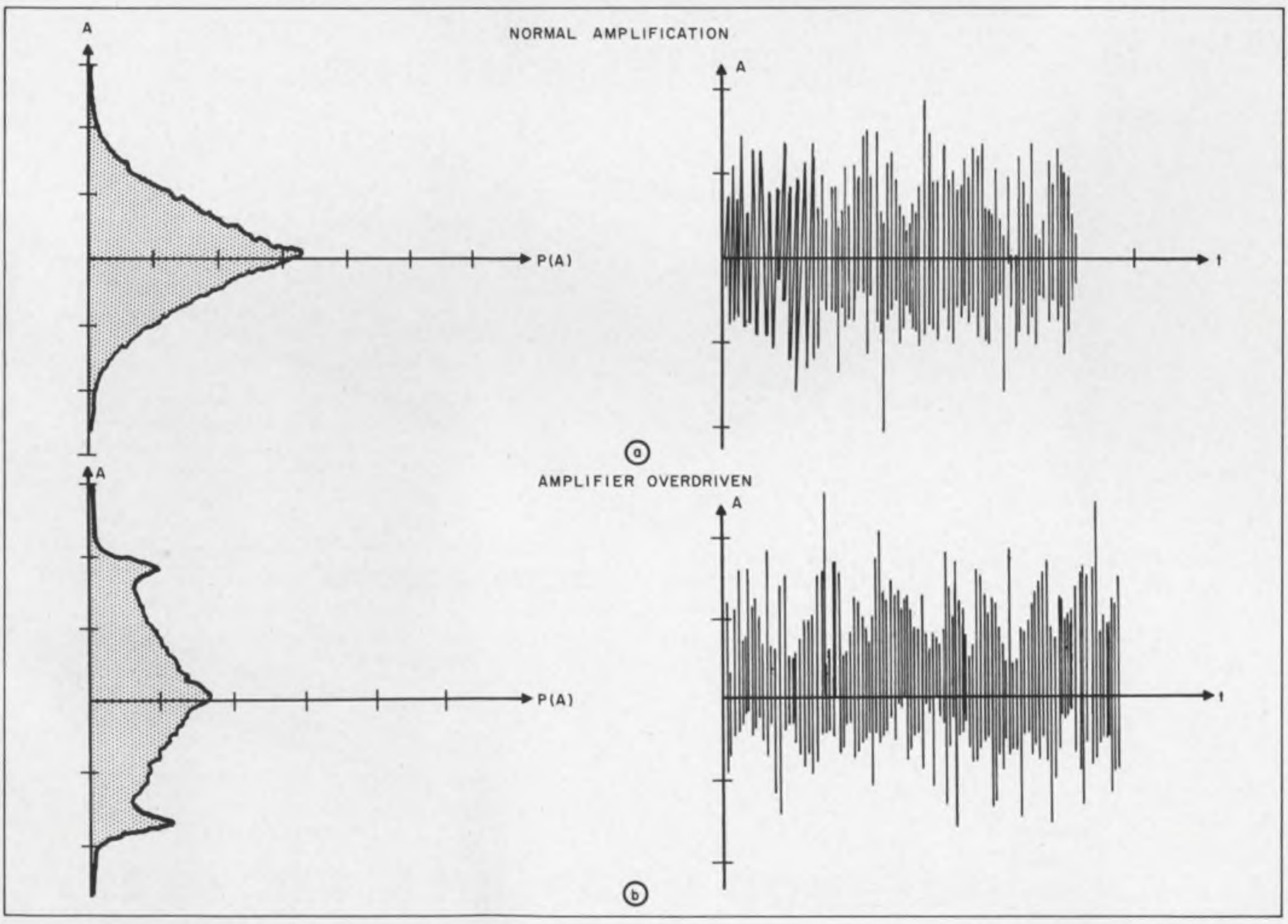


7. **Recording of the sample waveshape** can be obtained using the setup shown.

held in the zero-order hold circuit until the next sample is taken. The interval between samples averages about 60 μs. The stretched samples are available at the sample-hold output for connection to other measuring equipment. Since the statistics at this point are the same as those of the input signal, properties such as peak, average and rms can be measured with instruments of only moderate bandwidth capability. Statistical measurement can be made on extremely wide-band signals with a simple, inexpensive analyzer. A block diagram of the setup used to make the recordings shown here is shown in Fig. 7.

Figure 8a displays a portion of the sample-hold output and the density distribution of the noise present at the output of a wide-band amplifier. The noise is essentially "white" over a bandwidth of about 150 megacycles; that is, the noise contains components of all frequencies in this range. The same noise is shown in Fig. 8b, but this time with the amplifier overdriven slightly so that a small amount of clipping occurs. Note the sensitivity of this clipping exhibited by the density distribution.

Extension of the use of statistical signal description to the design and testing of voice communication channels, including multi-channel multiplexed systems can be readily seen. The use of such techniques in the optimum choice of quantization levels is a must. In short, any linear of quasilinear channel that is required to handle signals with the characteristics of a random variable lends itself to examination and synthesis by these statistical measurement methods. Proper care in measuring and data interpretation must be exercized, however, to assure accurate results. ■ ■



8. **Output of a wide-band noise source amplified** 40 dB and its probability density are shown in (a). The noise was plotted using a sampling oscilloscope. The same noise source was used to obtain the trace shown in (b) but in this case the amplifier was overdriven. Note the distortion in the probability density for the latter case.

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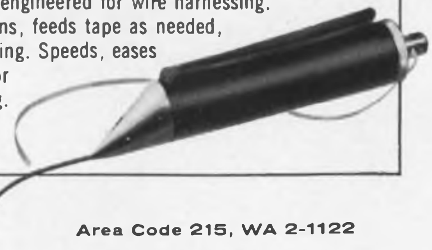

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ON READER-SERVICE CARD CIRCLE 38

Get ultralinearity from ramps.

Charging the timing capacitor from a constant current source improves and simplifies ramp generators.

Fast ramp generators with linearity better than 0.1% can be obtained by use of a constant-current source in addition to a current-sensing circuit in a feedback configuration. Three basic designs enable the engineer to choose the approach best suited to his particular need. Furthermore, ramp slope and amplitude variations of 200 to 1 and 20 to 1, respectively, have been demonstrated with ramp retrace times of better than 1 microsecond.

In comparison with conventional circuits using the Miller and bootstrap effects, these circuits afford the following advantages:

- Equal or better linearity.
- Greater slope range.
- Faster recovery time.
- Higher load handling ability.

The circuits' uses cover:

- Pulse width modulation.
- Analog-to-digital conversion.
- Accurate monostable operation.

Constant-current source is linear

The constant-current source constitutes the basic building block for all the ramp generators.

Its basic circuit is shown in Fig. 2. As operation starts, timing capacitor C is assumed to be initially discharged with $Q3$ ON. A step input of the desired ramp duration turns $Q3$ OFF, and $Q1$ starts charging C. The current through C develops a proportional voltage change across R, which is essentially in series with C. This voltage modifies the emitter current of $Q2$, which is equal to the base current of $Q1$.

The over-all effect of $Q2$ and R is to compensate for any load current variations. Should I_L decrease, for instance, I_C will tend to increase, if the collector current of $Q1$ is constant. The increase in I_C, however, will drive $Q2$ toward cut-off. This will decrease the base current of $Q1$, thus dropping its collector current and compensating for the decrease in I_L. This sequence of events is reversed for an increase in I_L.

Since the emitter current of $Q2$ is in general two orders of magnitude less than the current through C, the change in emitter current of $Q2$ will accurately follow changes in capacitor current, and by means of the current amplifying action of $Q1$ will cause C to charge linearly.

The effect of current through R_L is minimized by the current gain of $Q4$ (emitter-follower action). The bootstrapping action of $R3$ further improves the linearity by providing a feedback input to the base of $Q2$.

The linearity error factor is defined as:

$$L_e = (A_p - A_a)/A_p, \tag{1}$$

where A_p is the ideal amplitude at time t and A_a is the actual amplitude.

By making reasonable approximations, Eq. 1 can be reduced* to:

$$L_e = t/2\beta R_L C, \tag{2}$$

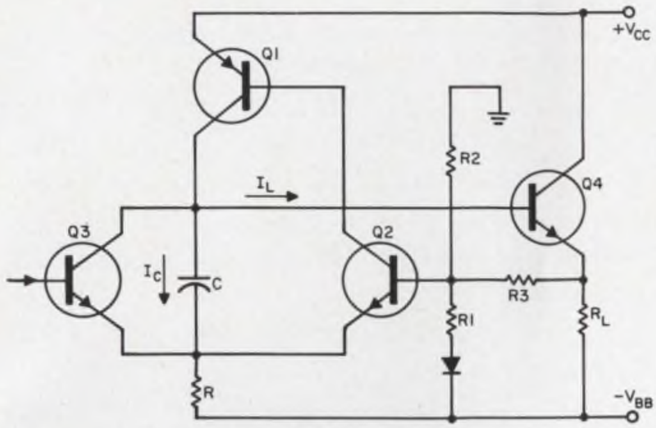
where $t = 1$ s, $R_L = 1$ MΩ, $C = 10$ μF, $\beta = 100$, $L_e = 0.05\%$.

It will be observed that the constant-current sources used in these three ramp generators are different from the general one presented above. The difference is that the bases of the current-

*The complete analysis of the circuit can be obtained by circling 309 on the Reader-Service card.

1. **The slope of the ramp** of the Type-III generator (visible on the scope face) can be adjusted over a wide range, as the author demonstrates.

Gilbert Marosi, Project Engineer, General Precision, Inc., Link Group, Sunnyvale, Calif.



2. **Ultralinear current source** uses only four transistors. All transistors should be high-speed, high-beta, low-leakage. In particular, Q2 should have high beta at low collector currents. Timing capacitor C should have flat characteristics over the operating temperature range.

sensing transistors of each constant-current source are connected to ground in all three cases. The reason for this is the need to discharge the timing capacitor at the end of each cycle rapidly and fully. Any base resistance will slow down the operation or result in an incomplete capacitor discharge. This latter effect would eventually prevent the operation of a generator altogether.

Type-1 ramp generator uses Schmitt trigger

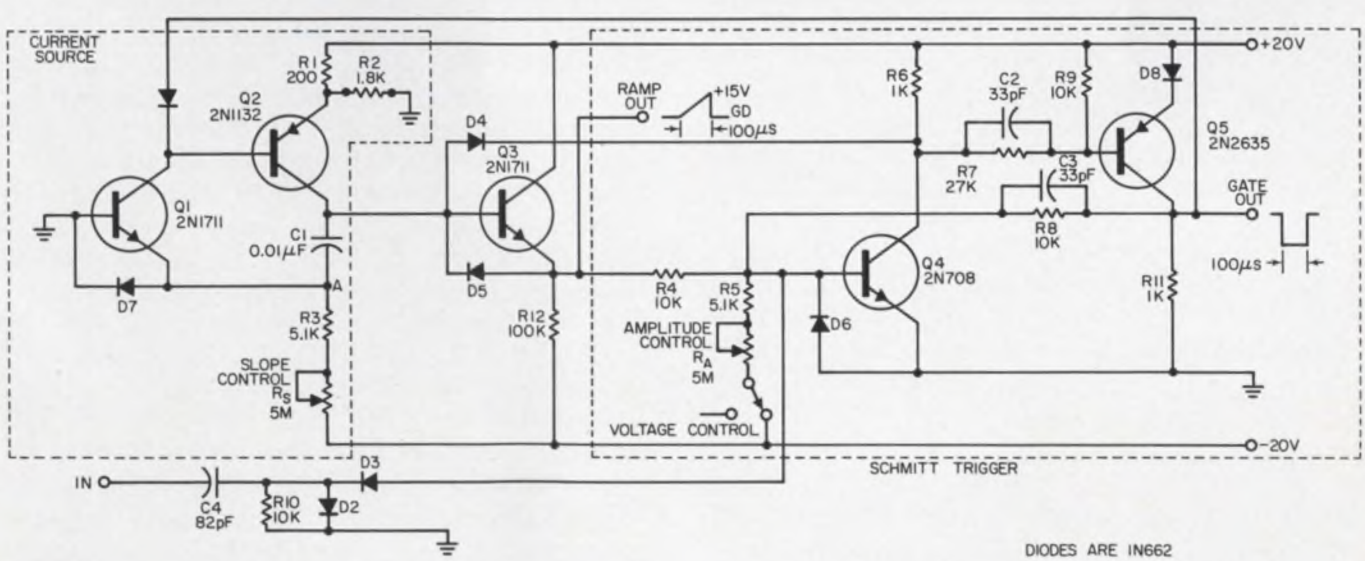
The complementary Schmitt trigger in conjunction with the linear current source make up a versatile ramp generator with both ramp amplitude and slope control as well as gate outputs. In Fig. 3, *Q4* and *Q5* comprise the complementary Schmitt trigger. *Q1* and *Q2* perform the linear charging of timing capacitor *C1* and *Q3* is an emitter-follower that furnishes a low-impedance drive to the complementary Schmitt and minimizes load current variations.

In the stable state *Q4* and *Q5* are ON. The emitter of *Q2* is at +18 volts while the collector of *Q5* is at +19.6 volts. *Q2* is therefore OFF, and *D1* is forward-biased. The supply voltage for *Q1* is provided by *Q5*. *Q1* is turned ON by the −20-V supply's causing an emitter current to flow through it. With *Q4* ON, the base of *Q3* is at +0.3 volt and *C1* is discharged. Since the emitter of *Q3* is essentially at 0 volts, the current needed to turn on *Q4* is provided by *Q5* through *R8*.

A negative trigger through *C4* and *D3* turns OFF *Q4* which in turn turns OFF *Q5*. Since there is then no base drive for *Q4*, it remains OFF. With *Q5* OFF and the emitter of *Q2* at +18 volts, *D1* is back-biased. *C1* is then charged linearly by the constant-current source *Q1* and *Q2*. A linear rise in voltage occurs at the base as well as the emitter of *Q3* owing to the charging of *C1*. When the voltage at the emitter of *Q3* reaches the point at which the current through *R4* exceeds the current through R_A and *R5* by the amount of base current needed to drive *Q4* into the active region, *Q4* starts to turn ON. This turns *Q5* ON, which supplies additional base drive to *Q4* and turns it ON harder. Consequently, both *Q4* and *Q5* saturate.

C1 now discharges rapidly through the base-emitter junction of *Q1*, and through *D4* and the saturated *Q4*. *D5* ensures a rapid ramp retrace at the emitter of *Q3* in the case of a capacitive load, since the charge on the external capacitor would back-bias the base-emitter junction of *Q3* whenever *C1* discharges. In such a case a path to ground is provided through *D5* and *D4*. A maximum step of 0.3 volt at the start of the ramp is made certain by *D7*, which clamps point *A* and the emitter of *Q1* to ground. *D7* also prevents the back-biasing of *Q1* by a sudden rush of current through *C1* due to any delay in the constant-current source action.

The period of the generator is obtained from:



3. **Type-I ramp generator** has ramp and gate outputs. Pulse width modulation can be obtained by applying a control voltage to amplitude control potentiometer R_A. Note separate slope and amplitude controls.

$$T = \Delta VC/\Delta I. \quad (3)$$

where ΔV is the increment of voltage across $C1$, and ΔI is the increment of current through $C1$. The end of the ramp occurs when the current through $R4$ exceeds the current through R_A by the base current of $Q4$. ΔV may therefore be expressed in terms of R_A, $R4$, the current gain of $Q4$ and the various drops in the circuit. The following equations can be derived:

$$(\Delta V - V_{be3} - V_{be4})/R4 = [(V_{bb} - V_{be4})/R_A] + (I_{c4}/\beta) + [V_{be4}/(R8 + R11)]. \quad (4)$$

Assuming I_{c4}/β and the current through $R8$ and $R11$ both to be small compared with the current through $R4$ and R_A:

$$\Delta V = [(V_{bb} - V_{be4})R4/R_A] + V_{be3} + V_{be4}. \quad (5)$$

Assuming that the base-emitter drops of the transistors are equal:

$$\Delta V = (V_{bb} - V_{be})(R4/R_A) + 2V_{be}, \quad (6)$$

$$\Delta I = (V_{bb} - V_{be1})/R_S. \quad (7)$$

The period of the ramp generator may now be calculated by substituting Eqs. 6 and 7 into Eq. 3.

$$T = [(V_{bb} - V_{be})(R4/R_A) + 2V_{be}]C/[(V_{bb} - V_{be})/R_S]. \quad (8)$$

It is seen from Eq. 8 that the period is inversely proportional to R_A and directly proportional to R_S. The amplitude of the ramp may be varied over a range of 20 to 1 either by potentiometer R_A or a control voltage at the bottom of R_A. The period in the latter case is:

$$T = [(V_c - V_{be})(R4/R_A) + 2V_{be}]C/[(V_{bb} - V_{be})/R_S], \text{ or,} \quad (9)$$

$$T = (V_c R4/R_A)/(V_{bb}/R_S), \quad (10)$$

if base-emitter voltage drops are neglected. The generator may then be readily pulse-width-modulated. The slope of the ramp may be varied over a range of 200 to 1 by R_S, with the period of 1 to 200 microseconds. $C4$ should be selected for the worst case, which here means the inability of $C4$ to block the current through $R8$ (with R_A at its maximum range) and any additional current for rapid turn-off of $Q4$. The ratio between $C1$ and $C3$ should be 20 to 1 for proper discharge of $C1$.

The design of the complementary Schmitt trigger is accomplished as follows. $R11$ and $R6$ are chosen according to the load current and rise time requirements. $R9$ is selected according to I_{co}.

$$I_{b5} = [(V_{cc} - V_{d8} - V_{c8})/\beta R11] + [(V_{d8} + V_{be5})/R9]; \quad (11)$$

$$R7 = (V_{cc} - V_{d8} - V_{be5})/I_{b5}, \quad (12)$$

where I_{b5} is the current through $R7$. Since $R4$ will essentially be connected across the base-emitter junction of $Q4$ at the end of the cycle, the current through $R8$ will have to be equal to the current through R_A and the base current necessary to turn ON $Q4$. In equation form:

$$I_{R8} = (V_{be4}/R4) + [(V_{bb} + V_{be4})/R_A] + (V_{cc}/\beta R6); \quad (13)$$

$$R8 = (V_{cc} - V_{d8} - V_{c85})/I_{R8}. \quad (14)$$

$R4$ has to allow at least three times the base current at the minimum expected ramp amplitude ($V_{R\,min}$); namely:

$$I_{R4} = 3(V_{cc} - V_{c84})/\beta R6, \quad (15)$$

so that:

$$R4 = (V_{R\,min} - V_{be})/I_{R4}. \quad (16)$$

Since $Q2$ should be back-biased when the circuit is in the stable state, the emitter of $Q2$ should be set to some value lower than V_{cc} so that $Q2$ may be cut off and to allow for maximum ramp amplitude. A divider consisting of $R1$ and $R2$ and capable of carrying 10 times the maximum capacitor charging current serves this purpose. $R1$ and $R2$ may then be determined as follows:

$$R1 = (V_{cc} - V_e)/10\,I_{c\,max}; \quad (17)$$

$$R2 = V_e/10\,I_{c\,max}, \quad (18)$$

where V_e is the maximum ramp voltage.

There are several important features associated with this circuit. First, the current drawn by the load does not affect the linearity of the ramp. By contrast, the normal method of using a transistor in the common emitter configuration as a current source results in a marked degradation in linearity as the load current increases. Second, the retrace of the ramp is typically no greater than 1 microsecond; this allows a high duty cycle (95%) and frequency division up to 20 to 1. Third, pulse width modulation is simply achieved by applying a control voltage to the amplitude control resistor.

Type-2 ramp generator depends on UJT

The design of the generator depicted in Fig. 4 hinges on the characteristics of the unijunction transistor. One particular advantage of this configuration over the others is the fact that no current is drawn by the unijunction transis or until it has fired, which improves the linearity of the ramp. In this circuit, $Q3$ and $Q4$ constitute the constant current scource. $Q1$ and $Q2$ are connected as a flip-flop which, together with unijunction transistor $Q5$, allows monostable operation.

In the circuit of Fig. 4, $Q2$ is normally ON and $Q1$ is OFF. With $Q1$ OFF, $D6$ is forward-biased; this in turn cuts OFF $Q3$ since this transistor's emitter is held at +18 volts. With $D6$ forward-biased, V_{cc} furnishes collector voltage for $Q4$ by way of $R13$. $Q4$ is set in the active region by the forward-biasing action of R_S and V_{bb}. The collector current of $Q4$ is $(V_{bb} - V_{be4})/R_S$. When $Q2$ is ON, $C3$ is held in a discharged state and $Q5$ is off. A negative pulse through $D5$ cuts OFF $Q2$ and turns ON *Q1*. With *Q1* ON, the voltage at the anode of *D6* is +16 volts and the voltage at the base of *Q3* is +17.3 volts. Thus *D6* becomes back-biased. The combination of *Q3* and *Q4* linearly charges *C3* up to the firing point of unijunction transistor *Q5*. The firing of *Q5* rapidly discharges *C3* and, at the same time, sends a positive pulse through *D3*, turning *Q2* ON and *Q1* OFF. *Q1* turns OFF *Q3*, and the circuit is back to a stable state.

Using the definition of Eq. 3, ΔV, ΔI and the period for this case may be calculated as follows:

$$\Delta V = aV_{cc}, \qquad (19)$$

where a is the stand-off ratio of *Q5*.

$$\Delta I = (V_{bb} - V_{be})/R_S. \qquad (20)$$

Substituting Eqs. 19 and 20 into Eq. 3:

$$T = (aV_{cc})R_S C/(V_{bb} - V_{be}). \qquad (21)$$

The flip-flop is designed as follows: *R7* and *R14* are chosen in the same manner as *R1* and *R2* of Fig. 3. *R13* and *R1* are selected so as to back-bias *D6* by 2 volts when *Q1* is ON, as well as to allow some current to be drawn from the collector of *Q1* when it is OFF. Accordingly:

$$R13 = (V_{cc} - V_{e3} - V_{be3} - \Delta V)/I_{c1}; \qquad (22)$$

$$R1 = (V_{e3} - V_{be3} - \Delta V)/I_{c1}, \qquad (23)$$

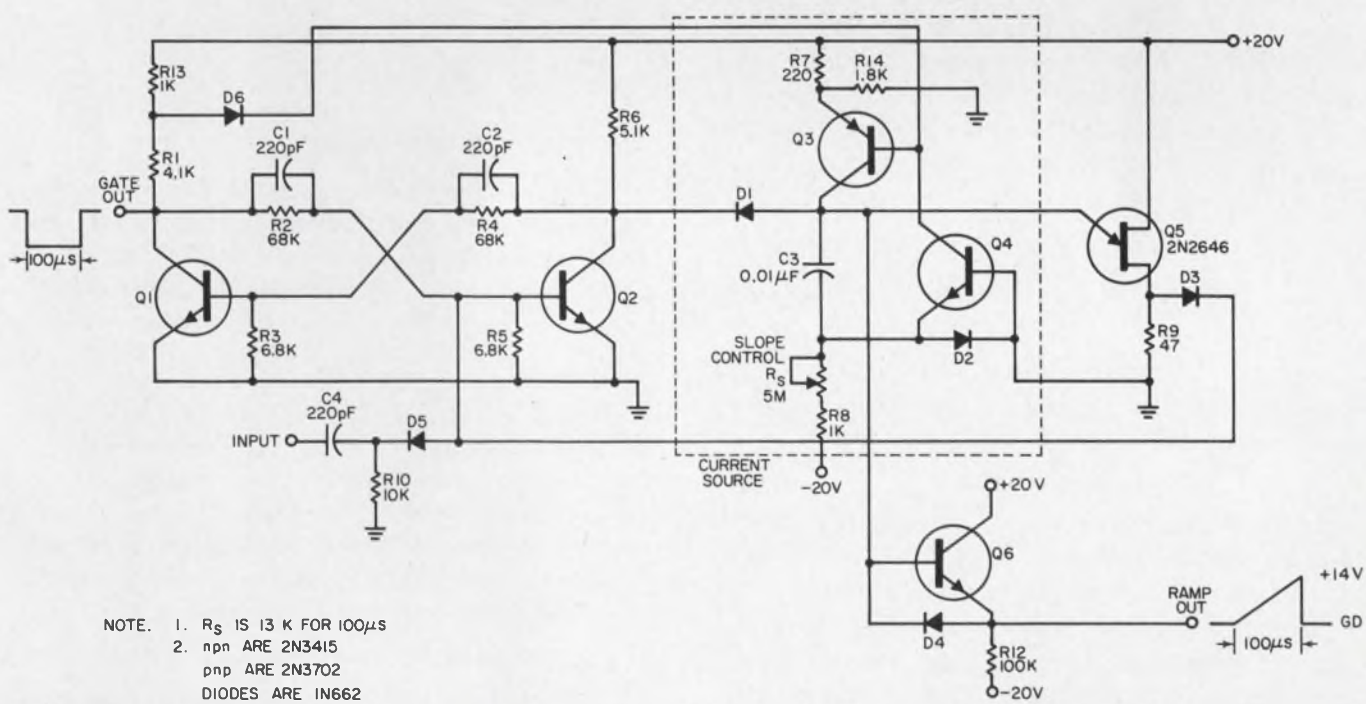
where V_{e3} is the voltage at the emitter of *Q3* and ΔV is the desired *D6* back bias with *Q1* ON.

Type-3 ramp generator is based on phantastron

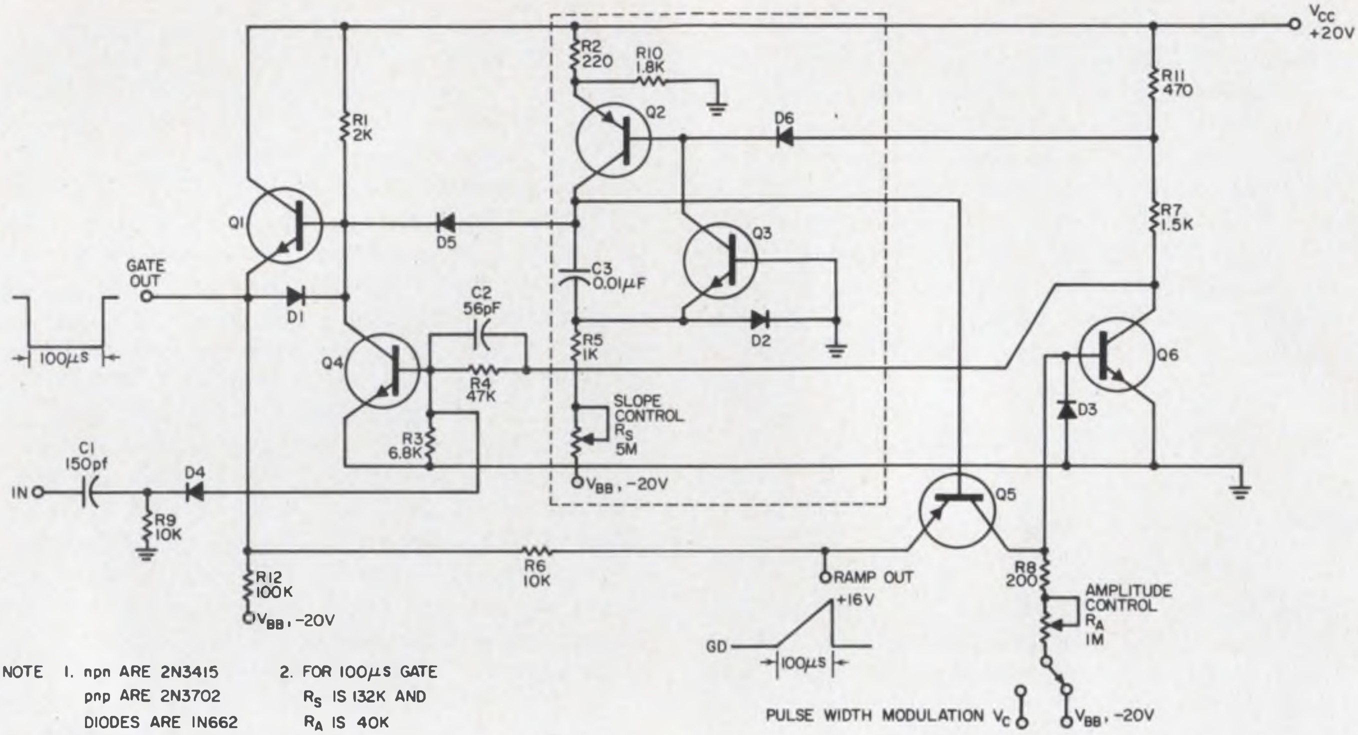
The ramp generator shown in Fig. 5 is a modification of the transistorized phantastron.[1] *Q4*, *Q1* and *Q6* comprise a monostable whose transient state is determined by the transfer of current from *Q1* to *Q6* through *Q5* at a rate proportional to the linear rise in voltage across timing capacitor *C3* and a back-biasing current set by R_A and the negative supply.

Q4 is normally ON, and *Q6* is OFF. With *Q6* OFF, the voltage at the anode of *D6* is +20 volts. *Q3* is ON, with a collector current set by R_S and V_{bb}. The supply voltage for *Q3* is furnished through *D6*. The emitter of *Q2* is held at +18 volts by *R2* and *R10*. With *D6* conducting, the base of *Q2* is at +19.8 volts; *Q2* is therefore OFF. With *Q4* ON, *C3* is discharged at +0.3 volt with *D5* forward-biased. *Q1* is an emitter-follower providing low output impedance drive to external loads. The emitter of *Q1* is at −0.7 volt with *Q4* saturated. *Q5* is normally OFF because *D5* and *Q1* are forward-biased. With *Q5* OFF, *D3* is forward-biased by the current through R_A, and with *D3* forward-biased, the base of *Q6* is at −0.3 volt; *Q6* is therefore cut OFF. A negative pulse through *D4* and *C1* cuts *Q4* OFF. The emitter of *Q1* then goes up to −20 volts, forward-biasing *Q5*, the base of which is still momentarily at +0.3 volt. The instantaneous current through the emitter of *Q5* is essentially $V_{cc}/R6$. This current minus the current through R_A goes into the base of *Q6* and turns it ON. In equation form: $I_{b6} = (V_{cc}/R6) - (V_{bb}/R_A)$.

When *Q6* is ON, the voltage at the anode of *D6* drops to +15 volts. Since the voltage at the emitter of *Q2* is +18 volts, *D6* is now back-biased. The constant-current source (*Q2* and *Q3*) now linearly charges *C3*. As in the other two generators, *Q3* monitors the current through *C3*, compensat-



4. **Type-II ramp generator** uses a unijunction transistor to improve linearity. This circuit is particularly useful for generating long (up to 1 minute), accurate gates. Ramp amplitude is determined by the firing point of Q5.



5. **Type-III ramp generator** is slightly more complex than the Type-I (Fig. 3). While basically the same as the Type-I, it has greater slope range and better gate driving ability. Note that it is a modified phantastron.

ing for any changes due to load. The constant-current charging of *C3* causes a linear rise in voltage at the emitter of *Q5*. This causes the emitter current of *Q5* to decrease, since the emitter of *Q1* is at +20 volts during this time. When the decreasing current of *Q5* essentially equals the current through R_A, the base current of *Q6* drops to zero. *Q6* then cuts OFF, turning ON *Q4* which dischares *C3*. At the same time *Q2* is turned OFF to guard *Q4* against an excessive collector current due to the base current supplied by *Q3* and amplified by *Q2*. With *C3* discharged, *D5* is forward-biased, cutting OFF *Q5* and ending the cycle.

The period calculations may be performed as follows (the notation of Eq. 3 is used):

$$\Delta I = (V_{bb} - V_{be})/R_S; \qquad (24)$$

$$I_{c5} = I_{R_A} \text{ at the end of the timing period.} \qquad (25)$$

$$I_{c5} = [V_{cc} - (\Delta V_c + V_{be})]/R6 = V_{bb}/R_A; \qquad (26)$$

$$\begin{aligned}\Delta V_c &= [V_{cc} - (V_{bb}\,R6/R_A)] - V_{be}\\ &= (V_{cc} - V_{be}) - (V_{bb}\,R6/R_A).\end{aligned} \qquad (27)$$

Substituting Eqs. 24 and 27 into Eq. 3:

$$T = [(V_{cc} - V_{be}) - (V_{bb}\,R6/R_A)]C/[(V_{bb} - V_{be})/R_S]. \qquad (28)$$

If the emitter-base drops are neglected, Eq. 28 may be simplified:

$$T = [V_{cc} - (V_{bb}\,R6/R_A)]C/(V_{bb}/R_S). \qquad (29)$$

Pulse width modulation may be achieved in this circuit by maintaining R_A constant and applying a control voltage to R_A. Eq. 29 then becomes:

$$T = [V_{cc} - (V_c\,R6/R_A)]C/(V_{bb}/R_S), \qquad (30)$$

where V_c is the control voltage. The slope may be varied in this circuit over a range of 500 to 1, with the period of 1 to 500 microseconds, and the ramp amplitude of 50 to 1. A 20-to-1 ratio should be maintained between *C3* and *C2* for proper discharge of *C3*.

R11 and *R7*, *R2* and *R10* are selected in the same manner as in the Type-2 generator. *R6* is chosen so that the current through it at the maximum expected ramp amplitude is at least three times larger than the base current of *Q6*. Or:

$$R6 = (V_{cc} - V_{max})/3\,I_b. \qquad (31)$$

Suit circuits to your needs

While all the generator types described above can be used in a wide variety of applications, each has been designed for a specific need. Thus, Type-1 and -3 generators are particularly suited for applications in pulse width modulation, analog-to-digital converters, high-frequency dividers and accurate monostables.

Type-2 is well suited to applications where accurate gates up to 1 minute long and with rapid retrace times are required. It is especially useful for timing capacitors up to 100 µF. Types-1 and -3 are not as efficient in this application, since they require the addition of speed-up capacitors for the discharge of the timing capacitors. ■ ■

Reference:

1. Gilbert Marosi, "Modified Multi Forms Phantastron Oscillator," ELECTRONIC DESIGN, XIII, No. 14 (July 5, 1965), pp. 46-48.

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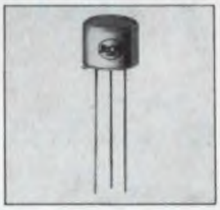

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h_{FE} 10V, 10mA	100-200	125-300	75-300	165-600	75-300	165-600	75-300	100-300 (50 min. @ 300mA)	
f_T typ.	175	175	80	80	80	80	80	150 min.	MHz
V_{CE} (SAT)	0.25 at 200mA I_C	0.3 at 300mA I_C	0.3 at 300mA I_C	0.25 at 200mA I_C	0.25 at 200mA I_C	0.2 at 100mA I_C	0.2 at 100mA I_C	0.3 at 300mA I_C	max. volts
Turn-on $I_C = 150mA$	75	75	—	—	—	—	—	75	max. nanoseconds
Dissipation** at 25°C Ambient	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	max. watts
I_C	Limited by P_T	Limited by P_T	0.3	0.2	0.2	0.2	0.2	1.0	max. amperes
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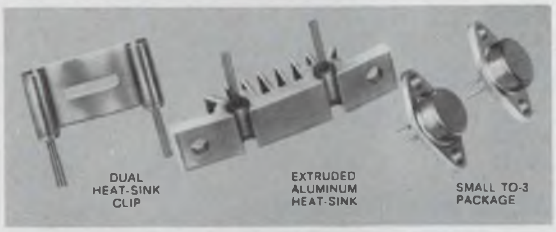

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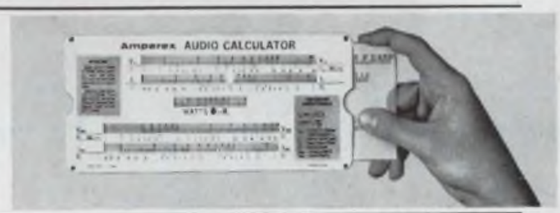

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PCA-2-9	3/4W, 9V D.C., 3 Transistor Amplifier
*PCA-2SLDC-9	Same as PCA-2-9 with off-on switch, less rectifier diode and filter capacitor
PCA-2-14	1W, 14V D.C., 3 Transistor Amplifier
PCA-2S-14	Same as PCA-2-14 with switch
PCA-2LD-14	Same as PCA-2-14 less rectifier diode
PCA-3B-18-1	4W/Channel Stereo Amplifier
PCA-6B-18	PCA-3B-18-1 with pre-amp for ceramic
PCA-4-9	1W, 9V D.C., 4 Transistor Amplifier for radio and ceramic cartridge
PCA-4-9A	Same as PCA-4-9 with tone control circuit
PCA-4-14	2W, 14V D.C., 4 Transistor Amplifier for radio and ceramic cartridge
PCA-4-14A	PCA-4-14 with tone control circuit
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TOMORROW'S THINKING IN TODAY'S PRODUCTS

ON READER-SERVICE CARD CIRCLE 41

Avoid relay misapplication. Case histories show that this can be done by giving the manufacturer more specs and applications data than sometimes meet the eye.

Thomas E. Castaldi, RBM Controls, Logansport, Ind.

The best way to order a relay is, obviously, to give the manufacturer complete specifications* and circuit information. He then not only can offer the best relay but, based on his expertise, provide circuit and application tips as well. But what constitutes "complete" specifications? They vary from application to application, making hard-and-fast guidelines difficult to establish.

Experience may be the best teacher here. Some specific examples show how "complete" information allowed a relay manufacturer to help a user to avoid misapplication. These case histories should give you some insight into the variety of data that the manufacturer needs, if he is to help you fully.

Example 1. Full specs lead to economy

A relay for a relatively straightforward application was required by Company A. After analyzing the electrical, environmental and reliability requirements, these specifications were sent to the relay manufacturer:

- SPDT pilot duty:110 volts ac.
- Button contacts: make before break.
- Pickup: 85 to 95 volts.
- Ambient temperature: 0° to 140°F.
- Life expectancy: 100,000 operations.
- Must operate with minimum of noise.

It happened that the relay manufacturer had three standard relay types capable of meeting these requirements. One of these was an economical, enclosed general-purpose relay that could be adjusted precisely during production to meet the pick-up and make-before-break requirements. This relay was entirely adequate for the user's needs, since his specifications covered all the important aspects of his application. Although this is a simple example, it demonstrates a point: Complete specifications frequently lead to substantial cost savings.

Example 2. Circuit diagram contains useful data

Company B needed a motor-starting relay for an application employing a single-phase motor. The motor to be controlled had the following characteristics:

- Full-load current: 25 A.
- Locked-rotor current: 132 A.
- Start capacitor: 400 μF.
- Run capacitor: 30 μF.

The company requested samples of potential units from the relay manufacturer, based on the following specifications:

- Continuous coil voltage: 336 V.
- Pick-up voltage: 340 to 360 V (hot).
317 to 345 V (cold).
- Maximum drop-out voltage: 170 V.
- To be used in the position recommended by the manufacturer.

With these specifications alone, the relay

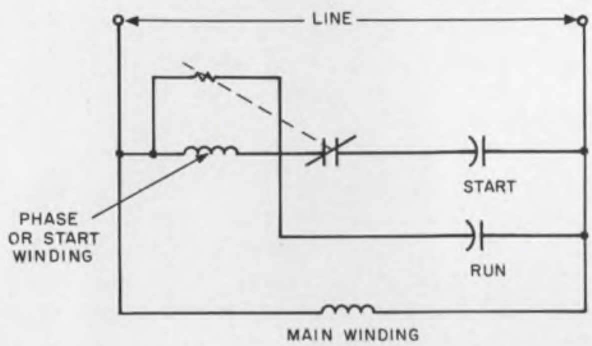
*For a comprehensive guide to writing complete relay specifications, see ELECTRONIC DESIGN's Relay Applications Directory, Nov. 29, 1965. Copies are still available at $5 each. Payment must accompany order.

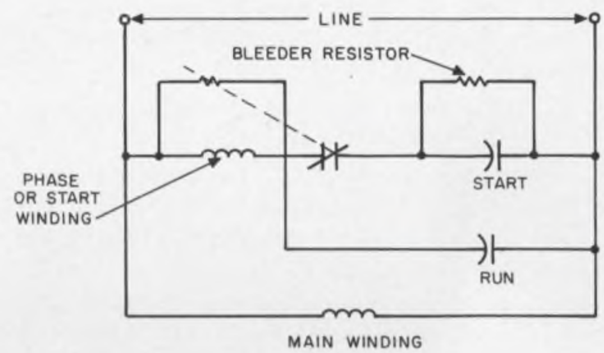
(Example 2., continued)

engineer could have supplied a sample relay. The customer, however, submitted his circuit diagram (below left) along with the above specifications. As it turned out, the circuit was the key to the proper application.

From this schematic and a description of the machine on which the motor was to be used, the relay engineer learned that a short ON time was characteristic of the motor's operation. This limited ON time would not allow sufficient time for the start capacitor to discharge internally. The normally closed contacts of the motor-starting relay might therefore weld when the motor was shut off, because of the discharging of the start capacitor. There could be serious motor damage.

Before furnishing a relay, the supplier discussed the situation with the customer. As a result, a bleeder resistor was added to the circuit (below right), to provide a discharge path for the start capacitor. Complete information in the hands of the supplier thus averted what could have been a costly breakdown.





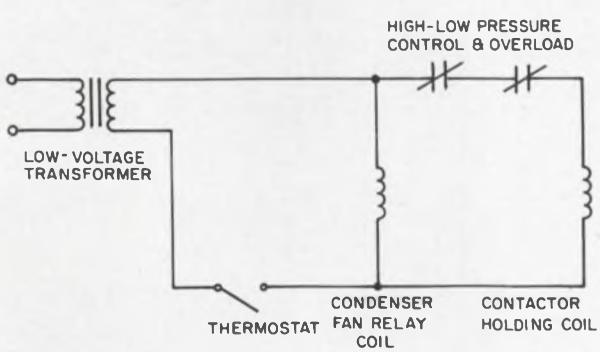
Example 3. Environment is important, too

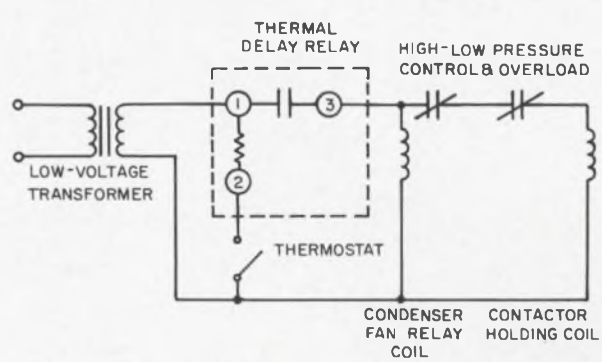
For some time a relay manufacturer had been supplying Company C with a contactor to control an air-conditioning condenser fan. Company C then began using a new-style room-temperature thermostat control. After the thermostat was brought into use, the customer started to complain about contacts welding on the load-handling contactors. The company informed the relay manufacturer of the problem, submitted the circuit diagram (below left) and asked if there was a solution.

From the supplied data, the relay engineer determined that the room thermostat controls had very light contact pressure, and were susceptible to chattering contacts caused by normal shock and vibration in the environment. The chattering contacts of the thermostat transmitted electrical pulses to the contactor, causing its contacts to chatter and ultimately to weld.

After the circuit had been studied, it was recommended that a thermal time delay be used between the thermostat contacts and the contactor's contacts or coil. This would prevent the contactor from following the thermostat contact chatter.

A time-delay relay was consequently installed (below right). It had normally open contacts, which closed when the heater coil was energized. Thus environment was a key factor in the solution of this problem.





(continued on p. 78)

Example 4. Circuit simplifications are possible

Company D submitted the following specifications to a relay manufacturer when requesting a time-delay-relay for a control application:

- Type of delay: time delay on pick-up.
- Input voltage: 24 volts dc ±10%.
- Timing range: 7 seconds ±10%.
- Method of initiation: remote.
- Termination: octal pin.
- Contacts: SPNC, low-current crossbar. SPDT, low-current crossbar.
- Temperature requirements: ambient range of 50° to 80°F.
- Reset time: 100 milliseconds.
- Life: 100,000 operations.

Although no circuit information was provided, the specifications were very complete. The customer was using a time delay on pick-up but had not considered a time delay on drop-out. This complicated the circuitry, which employed a pre-set time delay to control the amount of tape fed into a machine. Opening the tape switch started the timing action; at the end of the delay period a knife cut the tape to the correct length. The operation of the customer's circuit was as follows (below left):

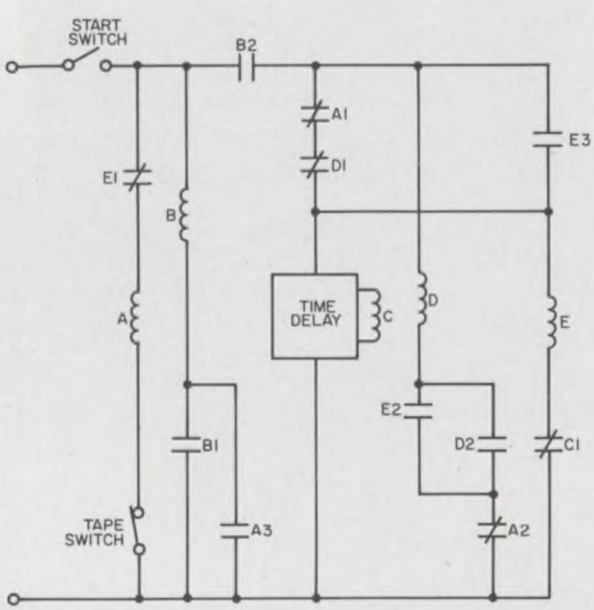
The electromechanical tape switch is closed when the start switch is actuated, causing relay *A* to pick up. The closure of contact *A3* energizes relay *B*, which latches through its contact *B1*. Relay *B* then supplies power to the remaining circuit through contact *B2*. However, since all branches have open contacts, no relay (*C*, *D*, or *E*) will energize.

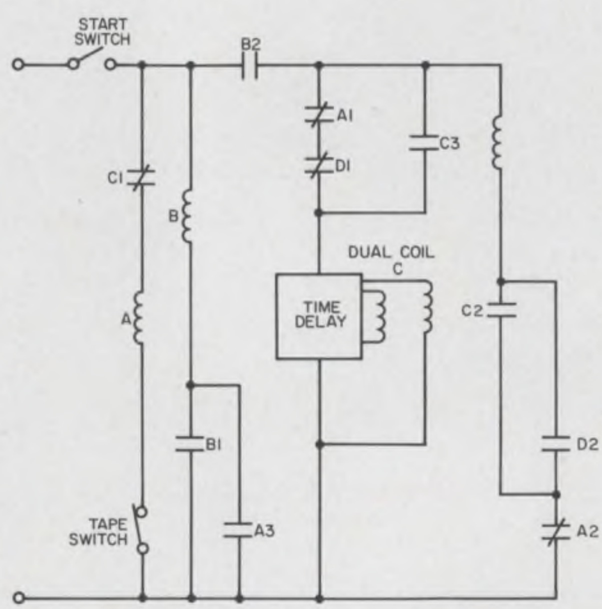
When the tape switch is opened by the advancing tape, relay *A* drops out, closing contacts *A1* and *A2*, and opening *A3*. This causes relay *E* to pick up and starts the time delay. Upon closure of contact *E2*, relay *D* picks up, opening one branch to both relay *E* and the time delay. Power is still applied to *E* and the time delay, though, through contact *E3*. At the end of the time delay, *C* picks up, breaking power to relay *E*. The de-energizing of relay *E* removes power from the time delay and coil *C*, and permits *A* to pick up if the tape switch is closed. This will not be the case, however, since the tape must be advanced before the tape switch can close. When *A* is energized, it removes power from *D*.

The time-delay relay was supplied as requested: no problems were reported. Later, however, the circuit diagram was submitted along with a request for additional samples. After examining the circuit, the relay engineer advised Company D that a single unit featuring time delay on drop-out could eliminate relay *E*. The revised circuit (below right) would operate as follows:

The electromechanical tape switch is closed when the start switch is actuated, causing relay *A* to pick up. The closure of contact *A3* energizes relay *B*, which latches through its contact *B1*. The lock-out relay, *B*, supplies power to the rest of the circuit through *B2*, but since all branches have open contacts no relay will energize.

When the tape switch is opened by the advancing tape, relay A drops out, closing contacts *A1* and *A2*, and opening *A3*. This causes *C* to pick up and start the time delay. Upon closure of contact *C2*, relay *D* picks up, opening one branch to the time delay.



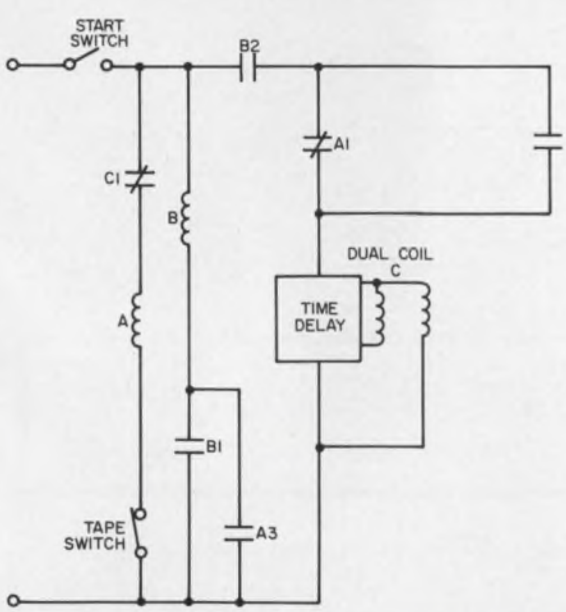


Power is still applied to the time delay, though, through contact *C3*. At the end of the time delay, *C* drops out by application of power to the bucking coil of the dual-coil relay. This in turn removes power from the time delay and coil *C*, permitting *A* to pick up if the tape switch is closed. This will not be the case, however, since the tape must be advanced before the tape switch can close. Energizing *A* then removes power from *D*.

This same circuit could be simplified further, with consequent cost reductions, by elimination of one relay coil, two normally open and two normally closed contacts. This was, in fact, done through the use of a dual-coil relay that operates on continuous duty without overheating. The actual unit used combines relays with solid-state components and offers a versatile time-delay range. The circuit, shown below, operates as follows:

The electromechanical tape switch is closed when the start switch is actuated, causing relay *A* to pick up. The closure of contact *A3* energizes relay *B*, but again no other relay will energize.

When the tape switch is opened by the advancing tape, relay *A* drops out, closing contact *A1* and opening *A3*. This causes *C* to pick up and start the time delay. At the end of the time delay, *C* drops out through application of power to the bucking coil of the dual-coil relay. This in turn closes *C1*, permitting *A* to pick up if the tape switch is closed. If the tape switch is not closed—which will be the case until the tape is advanced—power remains on both coils of *C*. When the tape is advanced and the tape switch closes, relay *A* picks up, removing power from *C*. ■ ■



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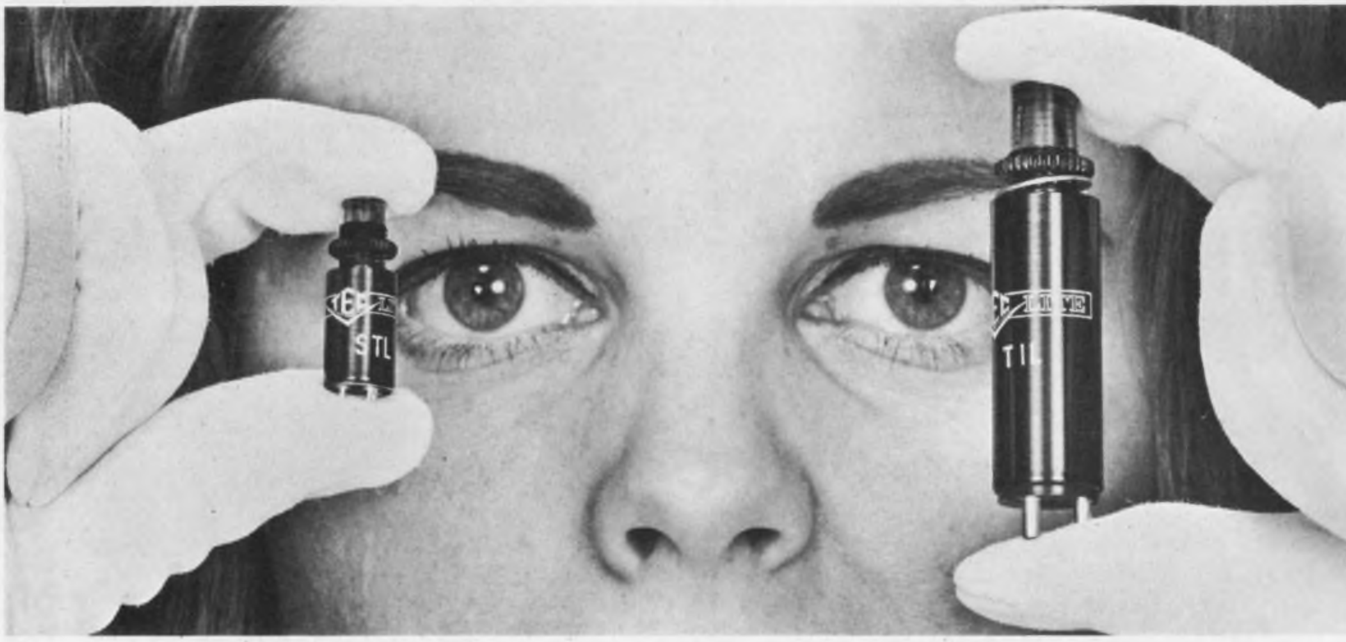

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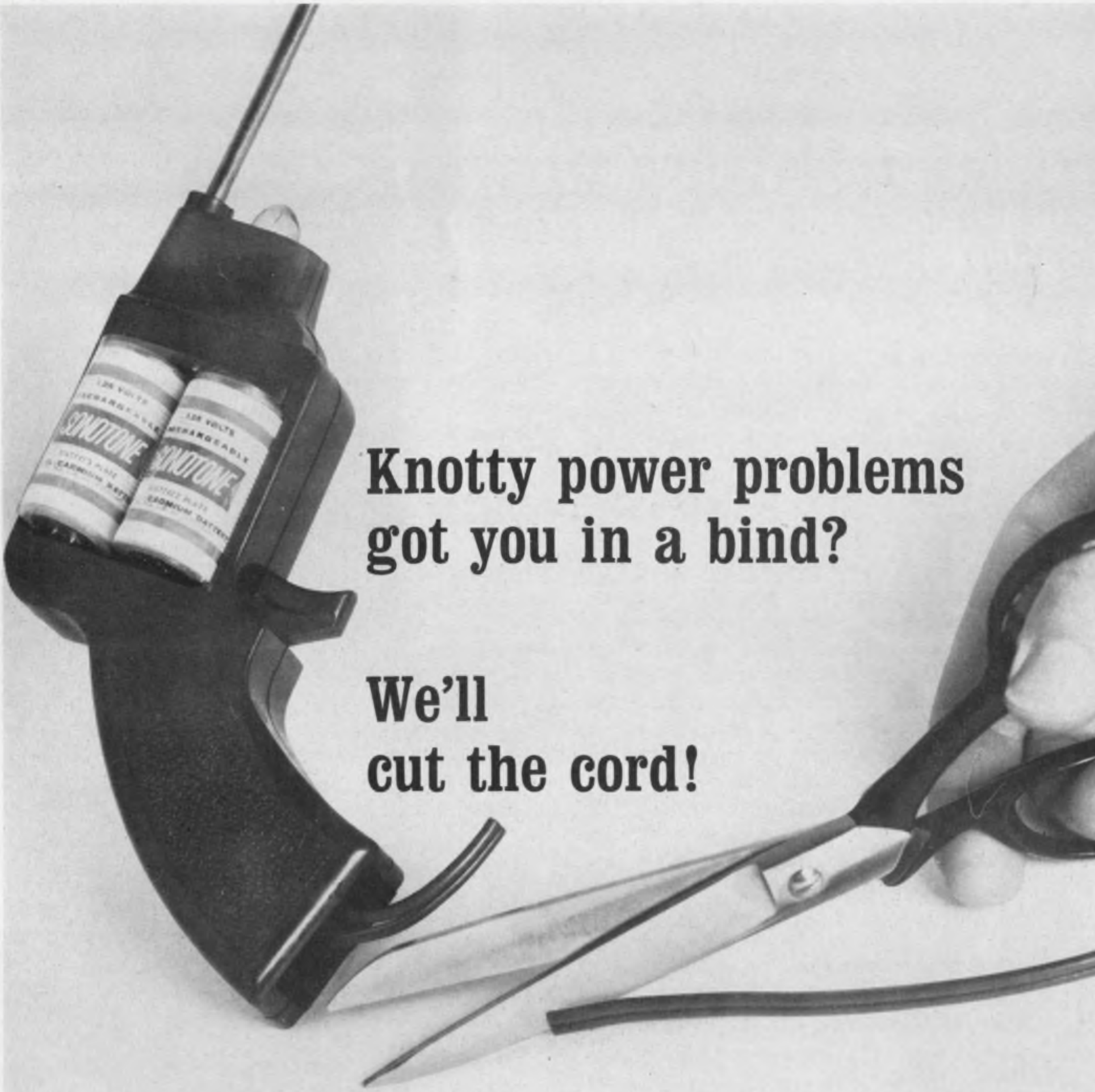

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ON READER-SERVICE CARD CIRCLE 44

Try low-resistance trimmers. If applied correctly, they can provide not only high resolution but other advantages as well.

By definition, a trimming potentiometer is a "set-it-and-forget-it" device, used for making circuit adjustments to compensate for normal system variations. As such, there is frequent need for it to produce the smallest possible incremental change in voltage—or in other words, it must have good resolution.

When choosing a wirewound trimming potentiometer for a particular application, designers normally apply conventional resolution theory, which for the most part equates high resolution with high resistance. This is not always the best approach, however, since low-resistance units can frequently meet all system design parameters while at the same time providing other important advantages. In such an alternate approach, fixed resistors are used with the potentiometer to provide the total circuit resistance required. The potentiometer resistance can then be relatively low, with its total resistance range being just sufficient to provide the desired output voltage swing.

Resolution depends on wire size

The resolution obtainable with a wirewound potentiometer is limited by the diameter of the resistance wire used. The smaller the wire diameter, the better the electrical resolution, since more turns of finer wire can be wound on a given mandrel length or angle.

But as wire diameter decreases, its resistance increases for a given alloy and configuration of the winding form. The result is a trade-off between resolution and resistance, with high-resolution potentiometers normally being in the high-resistance range.

Let us consider an example showing the advantages and pitfalls inherent in the selection of a high-resistance trimming potentiometer. Then let's examine the alternate approach, in which a relatively low-resistance unit is chosen. (Some basic definitions of resolution are given in the accompanying box as well as in Fig. 1.)

James A. Cunningham, Manager, Components Application Engineering, Weston Instruments, Inc., Weston-Archbald Div., Archbald, Pa.

Conventional approach meets requirements . . . but!

Assume that a system designer is faced with the problem of selecting a trimming potentiometer based on the circuit parameters shown in Fig. 2. He normally would consult a catalog or specification sheet to find a standard potentiometer that fits his needs. In this example, one possible choice would be a standard unit (such as Weston's Model 301 squaretrim), which has a total resistance of 50 K and a theoretical resolution of 0.086%.

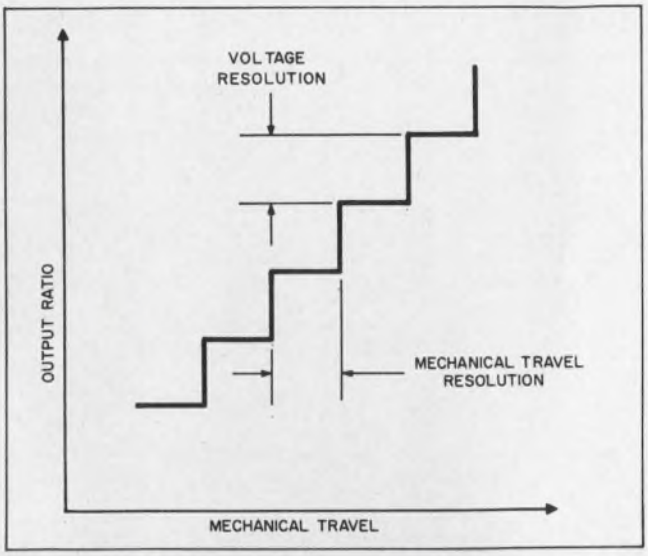
But what exactly has the designer obtained by his selection of a 50-K potentiometer? From the stated resolution of 0.086%, the smallest incremental change in voltage possible can be calculated from:

$$E_s = \text{Resolution x applied voltage}$$
$$= 0.00086 \times 200 = 0.172 \text{ volt.}$$

Therefore, as the potentiometer wiper is rotated across the resistance element, each turn of resistance wire will produce a change of 0.172 volt. And theoretically the desired output voltage of 100 volts $\pm 5\%$ (95-105 V) can be obtained in steps of 0.172 volt.

The selected potentiometer has an electrical angle of 336°, and so, with a total input of 200 volts, will produce a change of 0.595 volt per degree of wiper rotation. The desired output variation of 10 volts (100 V $\pm 5\%$) will therefore be obtainable with an angular wiper rotation of 16.8 degrees.

It is obvious from the above data that the selection of the 50-K potentiometer was theoretically correct and that the system's electrical requirement can be fulfilled. However, there is a potential flaw that the designer must make known to production, test and field-maintenance personnel. This flaw lies in the fact that the mechanical and electrical limits associated with the potentiometer make it possible for the design output voltage of 100 volts $\pm 5\%$ to be exceeded. The potentiometer can produce an output voltage variable from zero to 200 volts. And should it mistakenly be set too far outside the desired



1. **Both mechanical and electrical resolution** in a potentiometer depend on the diameter of the resistance wire used in the unit.

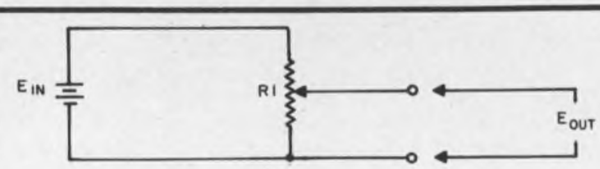
Definitions of resolution

Theoretical resolution: Used in wirewound linear potentiometers only. It is the reciprocal of the number of turns of the resistance winding in the actual electrical travel, and is expressed as a percentage.

Theoretical resolution = (1/N)100 in per cent, where: N = Total number of resistance-wire turns.

Mechanical resolution: In any specific portion of the resistance element, the maximum value of shaft travel in one direction per incremental voltage step. The relationship between mechanical and electrical resolution is shown in Fig. 1.

Voltage resolution: In any specified portion of the resistance element, the maximum incremental change in output ratio with wiper travel in one direction.



E_{in} = 200 volts dc

E_{out} = 100 volts ±5% (desired)

ΔE = 0-200 volts

E_2 = Smallest incremental change in voltage produced by one turn of resistance wire

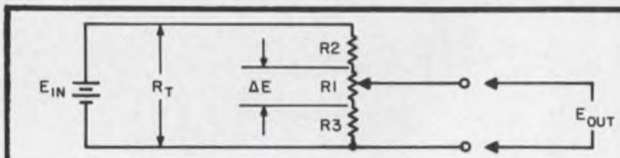
E_3 = Voltage produced per degree of wiper rotation

R_1 = 50,000-ohm potentiometer

Resolution = 0.086%

I_t = 0.004 A

2. **Conventional approach** for applying a trimming potentiometer for high-resolution applications normally results in selection of a high-resistance unit. Although circuit requirements can be met with such a unit, improper setting can result in circuit failure.



E_{in} = 200 volts dc

E_{out} = 95 to 105 volts (100 volts ±5%)

ΔE = 10.0 volts

E_2 = Smallest incremental change in voltage produced by one turn of resistance wire.

E_3 = Voltage produced per degree of wiper rotation

R_1 = 2500-ohm potentiometer

Resolution = 0.25%

R_2 = 23,750-ohm fixed resistor

R_3 = 23,750-ohm fixed resistor

R_t = 50,000-ohm total resistance

I_t = 0.004

3. **Low-resistance trimming potentiometers,** when applied properly, can provide high system resolution as well as protection from catastrophic system failure in the event of improper setting.

range, system failure can occur.

Alternate approach eliminates failure risk

Potential failures caused by improper setting of the potentiometer in the previous example can be avoided by selection of a lower-resistance potentiometer. The principal feature of this alternate approach is that it establishes suitable voltage end-limits that are within the system's reliable operational range.

To illustrate the alternate approach, we will maintain the original system parameters, including the required total resistance of 50 K (see Fig. 3 for circuit and parameters). The potentiometer used, however, will be a 2500-ohm unit, with a resolution of 0.25%.

A 2500-ohm value is selected on the following basis: The total ΔE required is only 10 volts (95 to 105 V). Therefore the total variable-resistance

Normal vs alternate design approach

Parameter	Theoretical values Normal	Alternate
Potentiometer resistance (R)	50,000	2500
Applied voltage E_{in} (volts)	200	200
Desired output voltage ±5% (volts)	100	100
Maximum output voltage possible (ΔE)	0-200	95-105
Nominal resolution (per cent)	0.086	0.25
Smallest increment of voltage (volts)	0.172	0.025
Voltage change/degree of wiper rotation	0.592	0.029
Actual electrical angle for desired output voltage (degrees)	16.8	336

element can be computed as follows:

$$\Delta R = \Delta E / I = 10/0.004 = 2500 \text{ ohms}$$

The 50-K system requirement is then satisfied by placing the 2500-ohm potentiometer in series between two fixed resistors of 23,750 ohms each. Now, not only is the desired 100-volt ±5% output produced, but the output is limited to the range of 95 to 105 volts regardless of the potentiometer setting. Note here that the fixed resistance values used are for the purpose of this example. In actual practice, standard values could be used, provided that when added to the value of the selected potentiometer, they meet the total resistance requirement.

Other improvements besides increased reliability also accrue from this alternate approach. The smallest incremental voltage obtainable with the 2500-ohm potentiometer ($E2$) can be determined from the value of ΔE as:

$$E_2 = \text{Resolution x } \Delta E$$
$$E_2 = 0.0025 \text{ x } 10.0 = 0.0250 \text{ volt.}$$

Therefore, as the wiper is moved across the resistance element, each turn of resistance wire will produce a change of 0.025 volt. Theoretically the desired output voltage of 100 volts ±5% can be obtained in increments of 0.025 volt.

If we assume an electrical angle of 336 degrees for the 2500-ohm potentiometer, each degree of wiper rotation will theoretically produce a 0.029 incremental voltage change. Thus the entire electrical angle of the potentiometer is used to produce the output voltage variation of 10 volts.

The results of both methods just described are summarized in the table. It is evident that the alternate design approach offers attractive advantages that make it well worth considering. ■ ■

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ON READER-SERVICE CARD CIRCLE 46

Get rid of cross-polarization

in edge-shunt slotted array antennas with only a partial grating placed across the center of the array.

Slotted waveguide array antennas have no back radiation or spill-over radiation. An edge-shunt slotted array antenna, which has inclined slots in the narrow wall for horizontal polarization, on the other hand, has the inherent disadvantage that the inclination of the slots produces a cross-polarized component, i.e., a vertical component. This induces fairly large lobes at approximately 45° on either side of the main beam in the horizontal plane. These cross-polarized radiation beams, which create false echoes when navigating in narrow channels or near massive targets, are suppressed by partial grating.

The edge-shunt slots are inclined with respect to the waveguide axis to couple to the field within the guide. Successive slots have opposite inclinations and the distance between slots is $\lambda_g/2$ in order to preserve the proper phase relations, as shown in Fig. 1 (λ_g is the wavelength in the guide). Thus the horizontal components of adjacent slots are in phase, but the cross-polarized components are out of phase. A group element factor, E_g, that indicates the interaction between adjacent slots by yielding the cross-polarized component, may be expressed as:

$$E_g = E_a(\phi)\,[E_A \exp j(\psi+\delta_A) - E_B \exp -j(\psi+\delta_B)], \tag{1}$$

where

$E_a(\phi)$ = element factor of slots,

E_A, E_B = amplitude of electromagnetic field across the slot,

$\psi = 2\pi d/\lambda \sin\phi$,

d = slot spacing,

ϕ = angle from normal to array axis,

λ = wavelength in free space, and

δ_A, δ_B = phase difference of electromagnetic field between adjacent slots.

For a resonant type of uniform array, we can, for the sake of simplification, assume that the element factor is equal to 1. Then $E_a(\phi) = 1$, $E_A = E_B = E_0$, $\delta_A = \delta_B = 0$. The group element factor, E_g, may be expressed as follows:

$$E_g = E_0 \sin(\psi/2), \tag{2}$$

which may be normalized with respect to E_0:

$$E_{g0} = \sin(\psi/2). \tag{3}$$

Consider an array with $2N$ slots. Each pair of slots forms a group element. Therefore the number of group elements is N, and the group element spacing is $2d$.

The cross-polarized radiation beams, E_{ce}, of an end-fed array are obtained as the product of Eq. 2 and the array factor of the group elements:

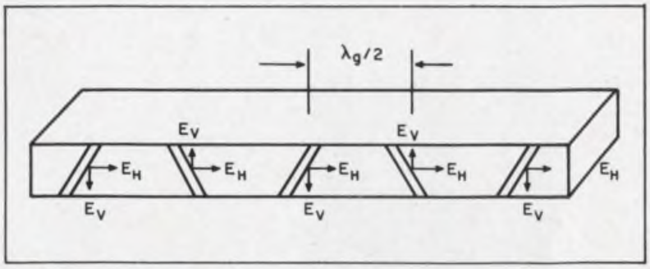
$$E_{ce} = [\sin N\psi \sin(\psi/2)]/N \sin\psi. \tag{4}$$

In the case of center-fed arrays, the array factor of the group element is the product of the array factor of the $N/2$ group elements on one side of the feeding point, the synthesis array factor, E_s, of both sides of the feeding point, and the group element factor E_{g0}. The synthesis array factor depends on the feeding branch. The conventional approach is to use a coaxial-to-waveguide adapter because of its small and simple construction. Then the horizontal components of the slots on both sides of the array are in phase and the cross-polarized components of the group elements on both sides of the array are out of phase. The synthesis array factor, E_s, of the group elements is estimated as follows:

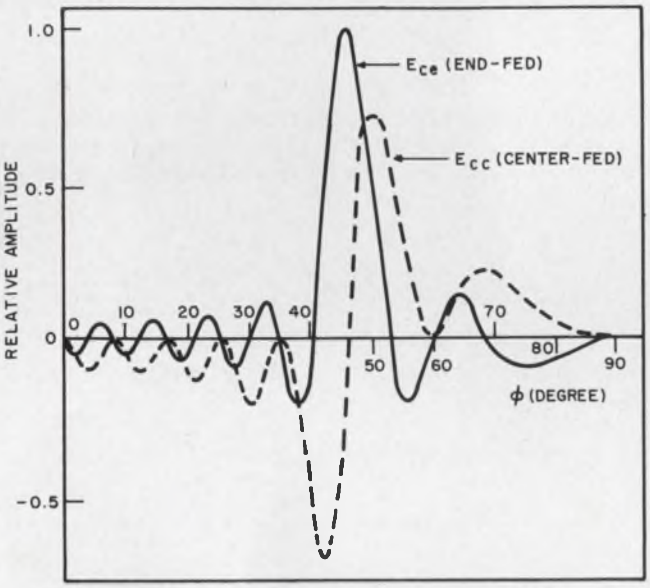
$$E_s = \sin(N\psi/2). \tag{5}$$

The cross-polarized radiation beams, E_{cc}, of a center-fed array may be expressed as:

Dr. Tadaaki Takeshima, Design Engineer, Radar Section, Kobe Industries Corp., Akashi, Japan.



1. **In an edge-shunt slotted waveguide array antenna** the horizontal field components, E_H, are in phase and the cross-polarized components, E_v, are out of phase for adjacent slots. The spacing between slots depends on the half-wavelength in the guide, $\lambda_g/2$.



2. **Calculated cross-polarized radiation pattern** shows difference between end-fed and center-fed arrays. The array has 20 slots, the wavelength is 32 mm and the distance between slots is 22.35 mm.

$$E_{cc} = [\sin^2 (N\psi/2) \sin (\psi/2)] / (N/2) \sin \psi = [\sin^2 (N\psi/2)]/N \cos (\psi/2). \quad (6)$$

The cross-polarized radiation beams, calculated from Eqs. 4 and 6, are given in Fig. 2, where $\lambda = 32$ mm, $d = 22.35$ mm and $2N = 20$.

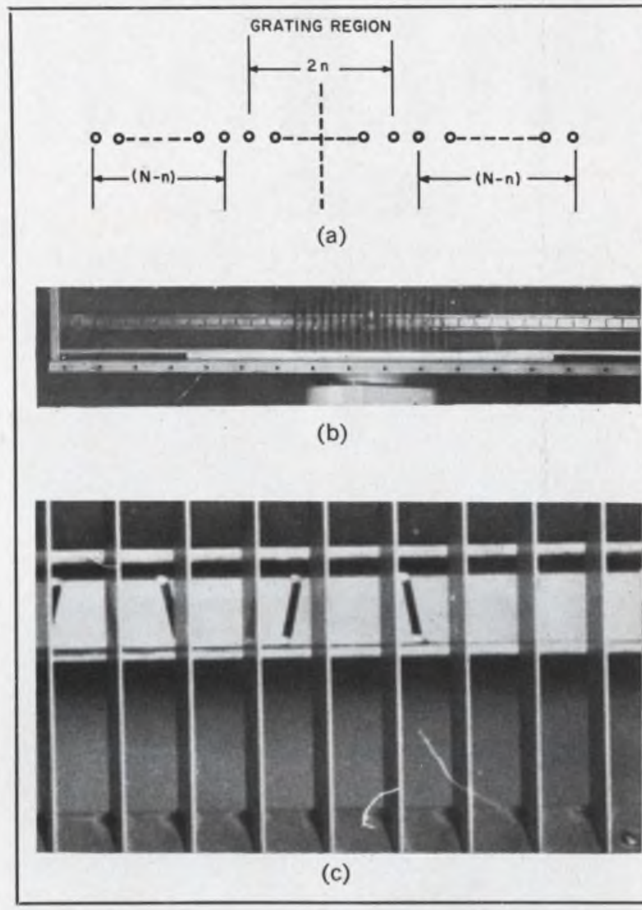
Partial grating removes cross-polarization

Gratings, acting as a filter, can effectively suppress cross-polarization, even if applied only across certain sections of the array rather than across its entire length.

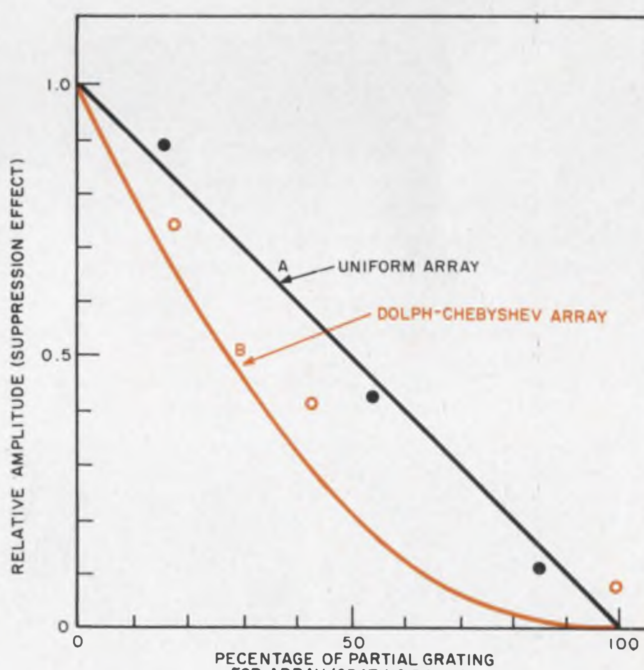
In an array with the partial grating on $2n$ slots of its center part, as shown in Fig. 3, assume that the cross-polarized radiation field from $2n$ slots is suppressed perfectly. In this case, the array factor, E_a, of $(N-n)/2$ group elements on one side of the array may be expressed as follows:

$$E_a = \{2 \sin[(N-n)\psi/2]\} / [(N-n) \sin \psi]. \quad (7)$$

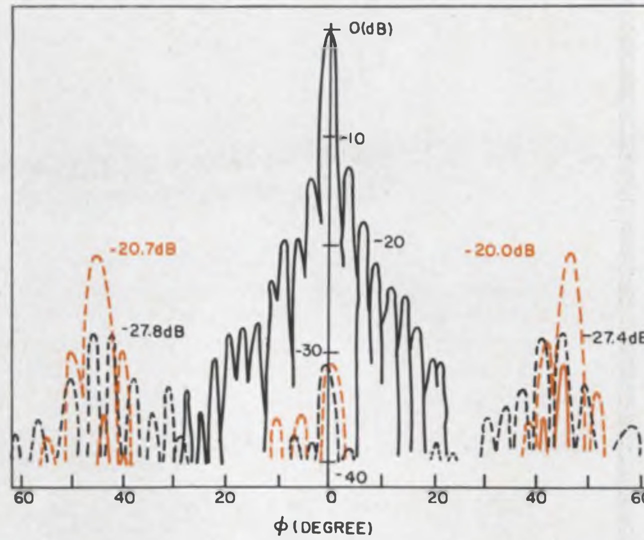
The array factor of both sides of the array E_{an} (for the end-fed type) is estimated as follows:



3. **Partial grating across the center section** (a) and (b) suppresses cross-polarization. For example, a grating, consisting of 16-mm wide and 0.5-mm thick metal plates, placed 12.5 mm apart, yields −20 dB attenuation (c).



4. **Measured suppression effects** show good correlation with calculated values. Dots indicate measured results, solid lines represent calculated ones. The effect is more pronounced for Dolph-Chebyshev arrays (in color). The results are valid for an array having 38 slots and operating at 9375 MHz.



5. **Cross-polarized radiation has been reduced** from −20 dB (color) to −27.4 dB with partial grating. The grating ratio is 54%. The tested array has 34 slots and operates at 9375 MHz.

$$E_{aa} = \cos\,[(N+n)\psi/2]. \tag{8}$$

The cross-polarized radiation beams with the partial grating are obtained as the product of Eqs. 7, 8 and 2:

$$\begin{aligned} E_{cp} &= 2\,\frac{\sin[(N-n)\psi/2]\,\cos[(N+n)\psi/2]\,\sin(\psi/2)}{(N-n)\sin\psi} \\ &= (\sin N\psi - \sin n\psi)/[2(N-n)\cos(\psi/2)]. \end{aligned} \tag{9}$$

The suppression effect of the partial grating is measured and calculated as shown in Fig. 4. Curve A is calculated from a uniform array, whereas curve B represents the case of a Dolph-Chebyshev array, designed with −30-dB sidelobes. The results of the pattern measurements are shown in Fig. 5, where a thin, vertical, parallel metal-plate grating designed for −20-dB attenuation is used.

Because the slot inclinations of the center part of the tapered distributed array are larger than those at the ends, the cross-polarized radiation fields are greater from the center part of the array than from the ends. If a 60% partial grating is used, the cross-polarized radiation beams will be suppressed to near the −38-dB level. The suppression effect is nearly equal to −16 dB, as shown in Fig. 4. The cross-polarized radiation field from the ends of the array therefore becomes negligible, and it is both unnecessary and uneconomical to install the grating across the entire length of the array aperture. The percentage of the partial grating of the array must be gauged according to system requirements. ■ ■

Acknowledgement:

The author wishes to thank Drs. S. Nishitake and S. Matsuda for their guidance and Y. Isogai for his assistance with the measurements.

Read off the life of pilot lights

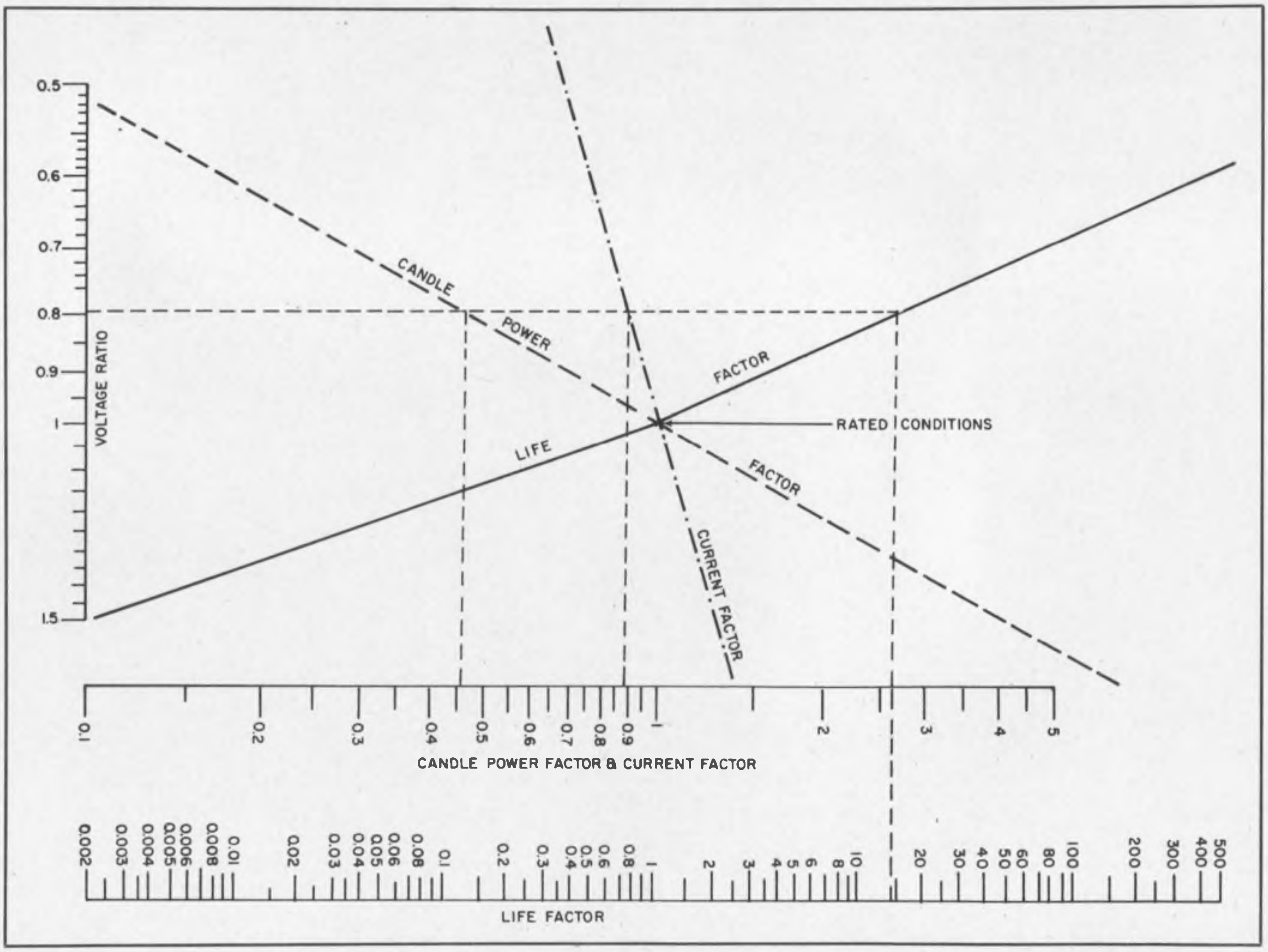
as a function of the operating voltage, current, candlepower from a simple nomograph.

Even the humble incandescent lamp may create intriguing problems if its lifetime must be evaluated rigorously in terms of its operating characteristics. The questions are: To what degree the voltage, the current and the candlepower change the life factor of the pilot light? The accompanying nomograph supplies the answers in a few simple steps.

Manufacturers recommend that the rated voltage of the lamps be 10 to 20% higher than intended applied voltage. This obviously does not apply where the duty cycle of the applied voltage is such that the lamp will be on for only short periods, where brightness is not important, and where blue lenses are used, since the blue-light output is low for low-temperature lamps.

To illustrate the use of the charts, consider this problem. A lamp is operated at 0.8 times its rated voltage. How will the life factor, current and candlepower change? From the graph we can read off the following: The life factor increases to 14.5 times its rated value, the current decreases to 0.88 of its rating and the candlepower drops to 0.46 of the rated value. ■ ■

Max H. Applebaum, Technical Writer, Thomas Organ Co., Sepulveda, Calif.



Reduce paperwork on MIL designs

with this index of items that are cross-referenced to military approval requirements.

You are bound to get into trouble on a military contract if you use a part that is not "preferred" or "approved." One way to avoid this is to know exactly what parts are preferred for any particular job. An impossible task? Not so, thanks to this cross-referenced index of the general equipment specifications.

General equipment specifications are included in practically all military contracts. Though they differ from service to service because each service has its own product and environment requirements, they always provide standards for selecting parts, materials, processes, design and construction of electronic equipment.

Nine of the commonly found specifications are:

MIL-I-983— Interior Communication Equipment, Naval Shipboard; Basic design requirements for

MIL-E-4158— Electronic Equipment, Ground; General requirements for

MIL-E-5400— Electronic Equipment, Aircraft; General specification for

MIL-P-11268—Parts, Materials, and Processes used in Electronic Communication Equipment

MIL-E-11991—Electronic, Electrical and Electro-Mechanical Equipment, Guided Missile Weapon Systems; General specification for

MIL-E-16400—Electronic Equipment, Naval Ship and Shore; General specification

MIL-T-17296—Test, Checkout and Evaluation Equipment, Guided Missiles (Fixed Installations); General specification

MIL-F-18870—Fire Control Equipment, Naval Ship and Shore; General specification

MIL-T-21200— Test Equipment for use with Electronic and Fire Control Systems; General specification for

These documents differentiate between those items considered best suited for an application and those regarded as less desirable. The acceptable items are classified as preferred or standard; all other items are not considered to be standard. While the former require no official approval, a written request, accompanied by supporting documentation, is required for all nonstandard items.

Knowing which items require written approval prevents the indiscriminate use of parts that may later cause delays and complicate the job.

Using the tables

Table 1 is a compilation of contract items that will often be examined for preferability. The list is separated into four sections:

A. Parts.
B. Materials.
C. Design, construction, processes, finishes.
D. Documentation, tests, identification.

A cross-reference number is listed against each entry and is keyed to Table 2, which lists the approval paragraphs for each specification. Note that paragraph numbers followed by two periods indicate that the approval requirements are detailed in a number of sub-paragraphs.

Given a military specification, one can quickly determine the required approvals.

As an example, assume you want to find the items that require approval in military specification MIL-I-983D(1). You would:

1. Find MIL-I-983D(1) in Table 2.
2. Note the paragraph numbers and corresponding Item Numbers (i.e., paragraph 3.6.4 corresponds to Item Number A6).
3. Note from Table 1, that A6 refers to electrolytic capacitors.
4. If the job calls for electrolytic capacitors, look up paragraph 3.6.4. in MIL-I-983D(1) and determine the approval requirements.

The table can also be used in reverse to check the coverage of particular items by a general equipment specification. For example, to find the approval requirements of connectors for MIL-E-5400H, refer to Table 1 and find the Item Number for connectors—A7. In Table 2, look up A7 in the Item Number list and MIL-E-5400H in the specification columns—paragraph 3.1.5* of MIL-E-5400H lists approval requirements for connectors. The asterisk (*) indicates that paragraph 3.1.5 refers to another military specification where the detailed requirements are listed; in this case, MIL-STD-454, Requirement 10. ■ ■

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Table 1. Item Names and Numbers

Item No.	Item Name
	Parts
A1	Adjusting devices using special threads
A2	Batteries
A3	Bearings, sleeve type
A4	Boots for push switches in watertight applications
A5	Capacitor, air dielectric
A6	Capacitor, electrolytic
A7	Connectors
A8	Control of parts design
A9	Control shafts and couplings
A10	Crystals
A11	Electron tubes (tube selection)
A12	Electron tube sockets
A13	Fluorescent lamps
A14	Fuseholders, clip type
A15	Gears, fiber construction
A16	Knife switches
A17	Locking devices (tube thread)
A18	Meters, high-sensitivity
A19	Miniature parts
A20	Nonstandard parts
A21	Nuts, sheet spring
A22	Power-plug locking devices
A23	Relays
A24	Selection of parts; standard parts
A25	Self-tapping screws
A26	Selenium rectifiers
A27	Semiconductor devices; transistors
A28	Set screws using other than hexagon socket heads
A29	Shock mounts and vibration isolators
A30	Terminal boards; terminal strips
A31	Transformers
	Materials
B1	Aluminum and aluminum alloys (chemical treatment
B2	Antiseize compound
B3	Cable (application and treatment)
B4	Castings; metals; alloys
B5	Ceramics
B6	Cotton fabric laminates
B7	Cotton- or wood-filled molding compounds
B8	Critical materials
B9	Electrical insulation; solventless varnish
B10	Fiberboard
B11	Fungus–inert material
B12	Glass
B13	Glass-bonded mica
B14	Insulated hook-up wire
B15	Insulating sleeving
B16	Laminates (sandwich core material)
B17	Magnesium; magnesium alloys
B18	Nonslip surface coating
B19	Nonstandard material (unspecified material)
B20	Organic material
B21	Plastics (selection, color application)
B22	Radioactive material
B23	Rope
B24	Rubber
B25	Solder and soldering flux
B26	Standard material (material selection)
B27	Substitution of materials

Item No.	Item Name
B28	Tape
B29	Thermoplastic material (rigid)
B30	Toxic material
B31	Unacceptable material
B32	Wire (insulated hookup)
	Design, construction, process, finish
C1	Antijamming
C2	Control panel layout (operating controls)
C3	Cooling with heat exchangers
C4	Design approval and design changes
C5	Deviations from specific design requirements
C6	Dial illumination
C7	Dielectric strength and insulation resistance clearance
C8	Drip-proof enclosures
C9	Electrical requirements
C10	Electronic tubes mounted horizontally
C11	Equipment weighing over 150 pounds
C12	Factory adjustment controls
C13	Finishes and special finishes
C14	General requirements
C15	Impregnating, encapsulating and embedding
C16	Interchangeability
C17	Interference reduction (filters)
C18	Maintenance
C19	Mechanized production (including printed circuits)
C20	Mock-ups
C21	Modulator construction
C22	Nonrepairable assemblies
C23	Overload protection, equipment protection and time delays
C24	Parts and unit mountings
C25	Preferred circuits
C26	Power requirements
C27	Processes; deviation from specified processes; nonstandard processes
C28	Protection against corrosion (dissimilar metals)
C29	Reliability
C30	Ship's hull (chassis or enclosure for active circuits)
C31	Soldering
C32	Special tools
C33	Threads in plastics
C34	Through-bolting or threading into watertight enclosures
C35	Tropicalization
C36	Waveguides and waveguide assemblies
C37	Working drawings
	Documentation, tests, identification
D1	Circuit labels
D2	Documentation; drawings; manuals
D3	Equipment errors
D4	General requirements for identification
D5	Identification markings and labels
D6	Preproduction (or design approval tests)
D7	Printed wiring
D8	Nameplates; nameplate facsimile; nomenclature
D9	Test equipment provisions; test sets
D10	Test point plan
D11	Test procedures
D12	Through-bolting in watertight enclosures
D13	Use of equipment subjected to shock test
D14	Wire coding; external wiring

(Table continued on p 94)

Table 2. Approval Requirements of Common Military Specifications

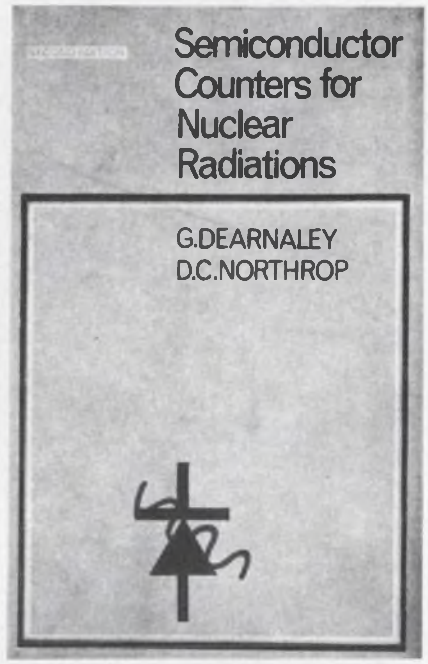
Item No.	MIL-I-983D(1)	MIL-E-4158C(2)	MIL-E-5400H	MIL-P-11268D(2)	MIL-E-11991B	MIL-E-16400F	MIL-T-17296D	MIL-F-18870C	MIL-T-21200F
A1						3.4.28.3			
A2						3.4.6		3.4.16.4	
A3						3.4.7.3			
A4	3.6.12.4								
A5		3.2.3*	3.1.3.1*		3.2.3.2.2.1*	3.4.9.2.1			3.1.4.1*
A6	3.6.4		3.1.3.2		3.2.3.2.1	3.4.9.1.1		3.4.16.13..	3.1.4.2
A7		3.2.16.8	3.1.5*	3.38		3.4.11*			
A8				3.3..					
A9								3.4.5.2	
A10							3.8.12		
A11		3.3.1.1.2	3.1.1.2.2	3.70..	3.2.3.38.2	3.4.31..*	3.8.22*	3.4.16.25.2	
A12						3.4.32			
A13								3.4.16.36.3	
A14						3.4.17			
A15					3.2.3.11	3.11.5.1	3.9.5.1		
A16								3.4.16.54.2	
A17	3.7.22.1					3.4.29.5			
A18						3.4.20.5			
A19		3.2.17				3.4.5			
A20	3.6.1.1	3.3.2..	3.1.1..		3.1.7	3.4.1..	3.8.1	3.4.16.2	3.1.1..
A21			3.1.27.5			3.4.28.15			3.1.27.5
A22	3.7.22.1.2								
A23	3.6.7.2			3.58	3.2.3.21	3.4.24	3.8.16		
A24		3.3.1			3.1.6		3.8.1	3.4.16.2	
A25				3.60.4		3.4.28.10		3.6.8.2	
A26					3.2.3.20.1				
A27	3.6.2*	3.3.1.1.2	3.1.1.2.2		3.2.3.38.1	3.4.31*	3.2.24*	3.4.16.48.5	
A28						3.4.28.12			
A29			3.2.3		3.2.3.24.4	3.11.8.4			
A30						3.4.11			
A31				3.67.1					
B1					3.2.1.10.1.1	3.6.3			
B2	3.7.11.5								
B3				3.7.1.2					
B4	3.4.8.3			3.17.2	3.2.1.13.3	3.11.1		3.7.19..	
B5	3.4.10				3.2.1.15				
B6	3.4.9.1								
B7	3.4.9.1								
B8							3.7.2		
B9	3.8.12..								
B10				3.14					
B11		3.4.4.1*	3.1.12*						3.1.13*
B12					3.2.1.16				
B13					3.2.1.16.1				
B14				3.22.2	3.2.1.21.1.2				
B15				3.33.7					
B16		3.5.7.2.1							
B17	3.4.8.2	3.4.12			3.2.1.10.2	3.5.7.2	3.7.6.3	3.7.19.10	
B18					3.2.1.18				
B19		3.4	3.1.1..		3.1.7				3.1.1..
B20								3.7.20	
B21	3.4.9.4							3.7.21..	
B22								3.7.9	
B23					3.2.1.9.6				
B24				3.20					
B25						3.11.3	3.7.4	3.7.10	
B26								3.7.1	

*Approval information will be found in another specification that is referenced in this paragraph.

Item No.	MIL-I-983D(1)	MIL-E-4158C(2)	MIL-E-5400H	MIL-P-11268D(2)	MIL-E-11991B	MIL-E-16400F	MIL-T-17296D	MIL-F-18870C	MIL-T-21200F
B27	3.4.2	3.4.1						3.7.7	
B28									
B29									
B30	3.4.6					3.5.3.1	3.7.4	3.7.10	
B31	3.4.3.1					3.5.3..			
B32				3.22.2	3.2.1.21.1.2				
C1			3.2.10						
C2				3.39.8		3.13.14		3.4.5.2	
C3		3.2.6	3.2.5					3.5.6.3	
C4	3.9.3.2			3.3.3					
C5		3.2							
C6	3.8.11								
C7	3.8.13								
C8									
C9				3.2.3..					
C10	3.7.22.1.1								
C11		3.2.32							
C12						3.13.10		3.4.5.3.1	
C13				3.26	3.2.1.12				
C14	3.2.3..				3.1		2.3		
C15	3.4.11.2					3.5.9.2			
C16						3.4.4..			
C17	3.8.4.2								
C18			3.2.12..						
C19		3.2.16..	3.2.1..						3.2.1.1
C20							3.9.2.2	3.11	
C21						3.3.2			
C22		3.2.16.4							
C23					3.3.10.2				
C24							3.4.6	3.5.14..	
C25						3.9.2			
C26									
C27	3.3..	3.5.1			3.1.7				
C28	3.4.15..	3.2.7*	3.1.8*		3.1.9*				3.1.8*
C29									
C30	3.8.5								
C31	3.8.6.3..	3.5.5*	3.1.23.1						
C32		3.2.31.2	3.1.28		3.3.19.2	3.11.17	4.5..		
C33	3.7.11.7								
C34	3.7.7								
C35				3.31..	3.3.20*		3.7.5.1		
C36					3.2.3.35.1				
C37	3.9.3								
D1		3.6.9.2							
D2	3.9.3..								
D3	3.9.7.2							3.3.4.3.2	
D4						3.14..			
D5			3.1.19.2						
D6			4.3					4.3.1	
D7	3.6.17								
D8		3.6.1..	3.4.1		3.5.3			3.13*	3.4.1
D9					3.3.18.1		3.6.3	3.2.3.4	
D10		3.2.30.1.1							
D11			4.5						4.4
D12	3.7.7								
D13	4.4.18								
D14				3.3.11					

*Approval information will be found in another specification that is referenced in this paragraph.

Book Reviews



Radiation and design: A helpful guide offered

Semiconductor Counters for Nuclear Radiations. G. Dearnaley and D. C. Northrop (John Wiley & Sons, Inc., New York) 459 pp. $12.75.

While the major purpose of this book is to describe techniques to analyze nuclear radiation, a design engineer concerned with the effects of radiation on semiconductors should find it helpful.

Thus Chapter 1, which describes the nature of radiation, can serve as a basic introduction. This information, combined with Chapter 10 ("Radiation Damage in Semiconductor Detectors") should prove helpful in predicting the effects of radiation on semiconductors in spacebound hardware. A discussion about the silicon p-n junction photocells (Chapter 9) can be applied in analyzing radiation damage to solar-cell panels.

For those designing instruments, both laboratory and industrial, the book is a good compendium of the latest radiation-measurement tools in the field. Reading the measurement requirements, one can spot and envision the needs for equipment and, possibly, develop a new instrument line.

The authors have demonstrated a rare ability to describe complex physical phenomena by simple mathematical treatment.

The book deserves a prominent place on the desks of nuclear physicists, nuclear-reactor control engineers and instrument designers. It could also serve as valuable background in designing for high-radiation environments.

—*Peter N. Budzilovich*

Electronics

Having Fun In Electronics, Leo G. Sands (Howard W. Sams & Co., Inc., Indianapolis). 160 pp. $3.25.

This book is for the person interested in learning about electronics through experimental construction projects. Several basic circuits, such as audio, communications, and power supply units, are presented to help the reader to develop his construction skills and understanding of basic circuits. As well as the projects to build, the book explains basic principles of operation, so that the reader can understand the circuit action.

Amplitude modulation

Understanding Amplitude Modulation, Irving M. Gottlieb (Howard W. Sams & Co., Inc., Indianapolis). 160 pp. $3.25.

The author sets out the principles used in the amplitude modulation of a carrier signal and describes the various types of systems, both tube and transistor, used to accomplish it. Various levels of modulation are discussed, and switching modulators are explained and illustrated. The various improvements that can be made in a basic system are also explained. Written for advanced amateurs, broadcast technicians, engineering students, and others, the text is more than an introduction but not a full engineering-level treatment.

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College			
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850 Third Avenue
New York, New York 10022

General study of amplifiers

Amplifier Handbook, Richard F. Shea (McGraw-Hill Book Company, New York). $37.50.

This volume gives comprehensive information on amplifier basics, amplifying devices and amplifier circuits to help solve everyday amplification problems. It is intended as a standard reference for practicing engineers, scientists and technicians on amplifying techniques in general and on specific circuits for a wide range of applications. It includes material that should permit the design of circuits, other than those presented, to fit individual needs. The text is divided into three major sections: fundamentals, devices and circuits. Emphasis throughout is on practical application, with theory and mathematics held to the minimum necessary for usability. With almost 1500 pages the book contains a profusion of reference material, including tables, specifications and similar data, compiled with a multitude of sources to help locate desired information quickly and easily. Over 1500 illustrations demonstrate important principles and procedure.

Dynamic programing

Introduction to Dynamic Programming, George L. Nemhauser (John Wiley & Sons, Inc., New York). 256 pp. $7.95.

This book deals with the theory and computational aspects of dynamic programming. It is an applied book designed for operations researchers, management, scientists, statisticians, engineers and social scientists. It tries to show when dynamic programing can be used and how to develop applications. The basic theory and computational methods are extended to cover stochastic and competitive models, nonserial processes and infinite stage systems. Applications to inventory theory, allocation problems, control theory and chemical engineering design are illustrated with numerous exercises.

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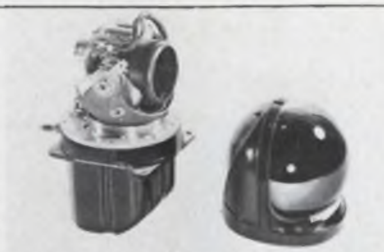

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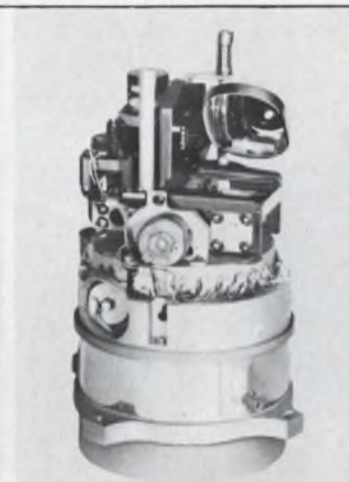

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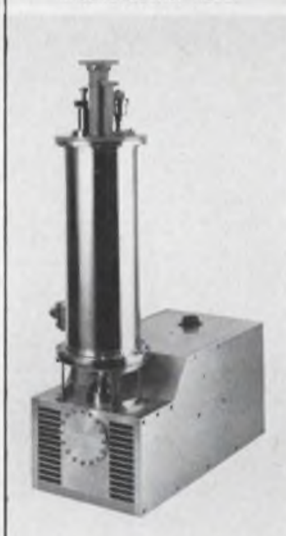

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Oscilloscope measuring

Oscilloscope Measuring Technique, ("Philips Technical Library") J. Czech (Springer-Verlag New York, Inc.) 620 pp. $15.80.

Theory and design techniques relating to modern oscilloscopes with information on means of using the instrument, photographic recording and large-screen projection of oscillograms are covered in this text. Eighteen chapters are devoted to detailed descriptions of measuring techniques in different fields. This is thus a handbook on uses of the modern cathode-ray oscilloscope in research, development and control. A valuable feature is the extensive collection of reproduced oscillograms from the author's collection, showing examples from work in electronics, acoustics, optics, mechanics and other branches of pure and applied science.

Control systems

Automatic Control Systems Engineering, Vol. I. A. W. Langrill, Jr. (Prentice-Hall, Inc., Englewood Cliffs, N. J.) 376 pp. $17.25.

The first two volumes devoted to automatic control systems engineering deals with linear control theory, while the second is concerned with nonlinear control systems theory. Volume I comprises two main sections: Part I, Dynamic Systems Analysis, and Part II, Basic Control Systems Theory. This text concludes with Appendix A, a table of Laplace transform pairs and Appendix B, the Routh stability criterion. Engineering personnel desirous of a working knowledge of control systems engineering will find this book a source of reference.

Digital tape drives

Digital Tape Drives, James E. Taunt (The Business Press, Elmhurst, Ill.), 161 pp. $7.45.

This book is intended for people associated with digital computers—operators, programers, analysts, managers and consultants. This text is directed to those individuals who want to learn about digital tape drives. Found at the end of each chapter is a summary as well as questions to further the readers, understanding. The information made available in this book is particularly useful when investigating an unknown computer system, when trying to increase the efficiency of an existing computer system, or when planning increased capacity.

Engineering management

Successful Engineering Management, Tyler G. Hicks (McGraw-Hill Book Company, New York). 287 pp. $8.50.

This is a guide for the engineer or scientist who holds, or seeks to hold, a managerial position. It devotes special attention to practical problems of delegating, instructing, guiding and controlling people. It aims to show what to do, when to do it, and how to do it. The book

deals with engineering management in all areas of modern technology, including engineering design, manufacturing, plant operation and maintenance, and construction projects. Numerous checklists, organization charts, control forms, and tabulations are included. The author attempts to show the reader how to evaluate his chances for advancement, to begin his rise up the management ladder, to check his progress, and what to do if his advancement is slower than he thinks it should be

Plasmas

The Particle Kinetics of Plasma, I. P. Shkarofsky, T. W. Johnston, and M.P. Bachynski (Addison-Wesley Publishing Company, Inc., Reading, Mass.). 518 pp. $17.50.

This book describes the fundamentals of particle kinetics as they apply to a gaseous plasma. It applies these ideas to develop basic equations for plasmas under various conditions. Although only the behavior of gaseous plasmas is discussed explicitly in this book, some of the concepts are equally applicable to plasmas in the liquid or solid state.

This volume is intended both as a reference for research and as a text for a graduate course on plasma kinetics. Where possible, the subject matter is developed from first principles in sufficient detail to enable the reader to follow the derivation closely. A knowledge of vector and matrix calculus, differential equations, atomic physics, and electromagnetism is assumed.

Sweep generators

101 Ways To Use Your Sweep Generators, Robert G. Middleton (Howard W. Sams & Co., Inc., Indianapolis). 160 pp. $2.95.

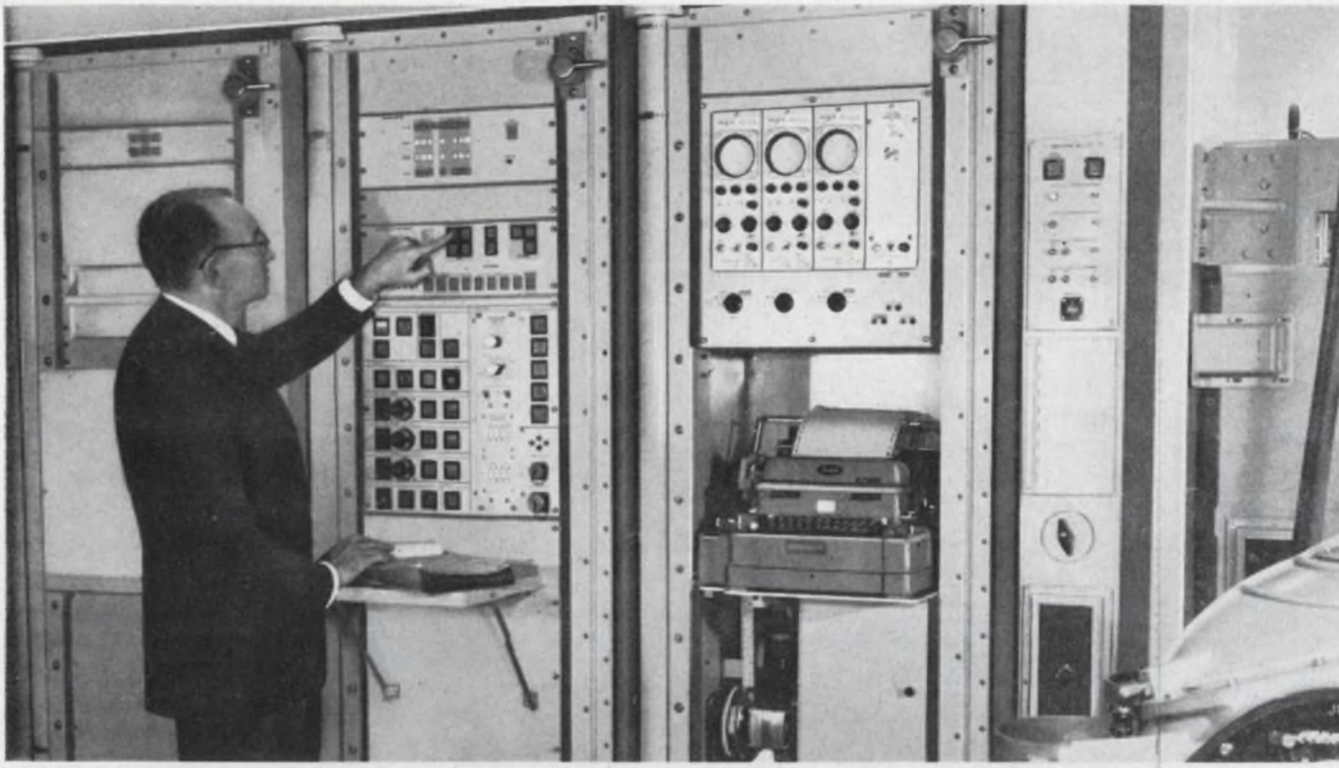
This book comprehensively covers the practical uses of a sweep generator. Specific sections cover the use of audio and RF generators for checking and calibrating test equipment, making audio amplifier tests,

and performing RF and IF alignment and tests. It also discusses special uses in color-TV receivers. Each application includes full data on connections required, additional equipment needed, proper test procedure and evaluation of results. There are more than 250 illustrations, waveforms and diagrams.

Control systems

Introduction to Nonlinear Automatic Control Systems. Rajko Tomovic (John Wiley & Sons, New York). 172 pp. $7.50.

The stress is on the fact that the presence of nonlinearities causes important qualitative changes in system behavior. Therefore, the parallel between linear and nonlinear mathematical models is always kept in mind. An important part of this book is devoted to experiments with simulation models. The analog computer is used experimentally to give insight into the physical characteristics of nonlinear systems.



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Forget it. When you're working on systems as formidable as the continuously evolving fleet ballistic missile system, the challenge to the support equipment engineer is at least equal to that faced by the primary systems or product engineer. Maybe more. More, because our people are not only conceiving and developing their equipment to evaluate and exercise the multiplicity of systems and subsystems of the prime system... they're also creating simulators for the primary equipment so that the evaluating systems can be exercised... all in parallel with or ahead of the development of the missile guidance and fire control system itself! ■ The equipment is then used to simulate flight control loops in the development stage of the missile. Later, you're likely to find this same equipment on the launching pads, firing developmental missiles. ■ All in all, our way is admittedly tougher than the "after the fact" support systems work you may have experienced someplace else at some other time. But if you've outgrown that experience, we promise you the kind of new assignments that will help you forget it. Like these:

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Phase-shift oscillator cuts cost and size of VCO

A phase-shift oscillator and a frequency-determining circuit, combined in the configuration shown below, yield a simple voltage-controlled oscillator. Transistors with very low betas can be used in the phase-shift oscillator, since the bias network is not a part of the frequency-selecting circuit. (When it is, as in conventional phase-shift oscillators, the designer usually has to degrade the beta of the transistor in order to maintain the network's stability.)

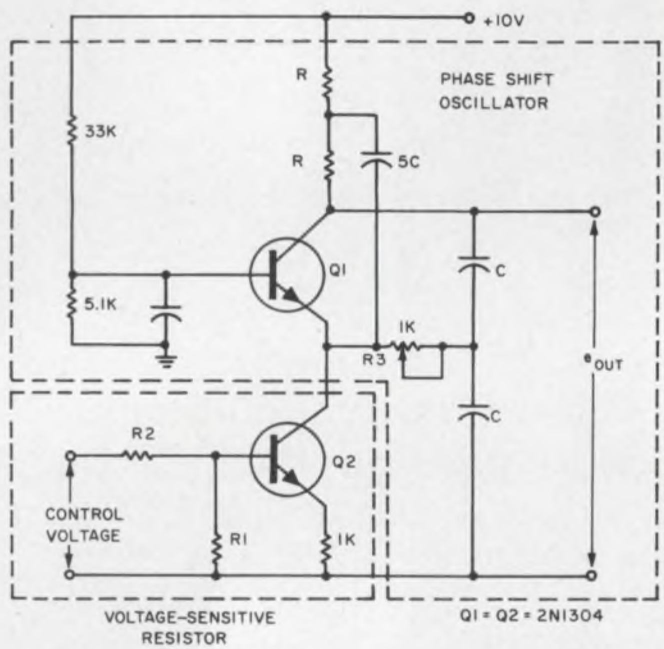
The circuit (see schematic) is particularly useful in telemetry systems and some analog-to-digital conversion schemes, where full advantage can be taken of its compact size and not too critical component tolerances.

The center frequency is given by the conventional formula:

$$f = 1/2\pi RC,$$

which may be adjusted with *R3*.

The frequency is varied by controlling the resistance of the emitter of the phase-shift oscillator. The emitter leg of *Q1* is the transistor *Q2*, which acts as a voltage-sensitive resistor. The center control voltage and the range of dc control voltage may be varied by the proper selection of *R1* and *R2*. Their exact values depend on the source characteristics.



Phase-shift VCO is designed with separate bias and frequency-selecting circuits, to permit the use of transistors with very low betas.

The linearity of this circuit, designed for a center frequency of 9.5 kHz, is about $\pm 3\%$. The components are all standard. The replacement of transistors will generally require readjustment of *R3*.

Saul A. Ritterman, Assist. Professor, Bronx Community College, N.Y.

VOTE FOR 110

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Microcircuit plus capacitor make simple one-shot

A microcircuit logic block with one external capacitor can be used to provide a fixed pulse whenever an input goes from a high to a low state. The circuit (see schematic), is implemented with an RTL block (Fairchild 910 or 914 would be suitable), although DTL or other logic forms could also be used. Note that the small numbers at junctions refer to pin connections on a TO-5 or epoxy package.

Basically, the operation is as follows.

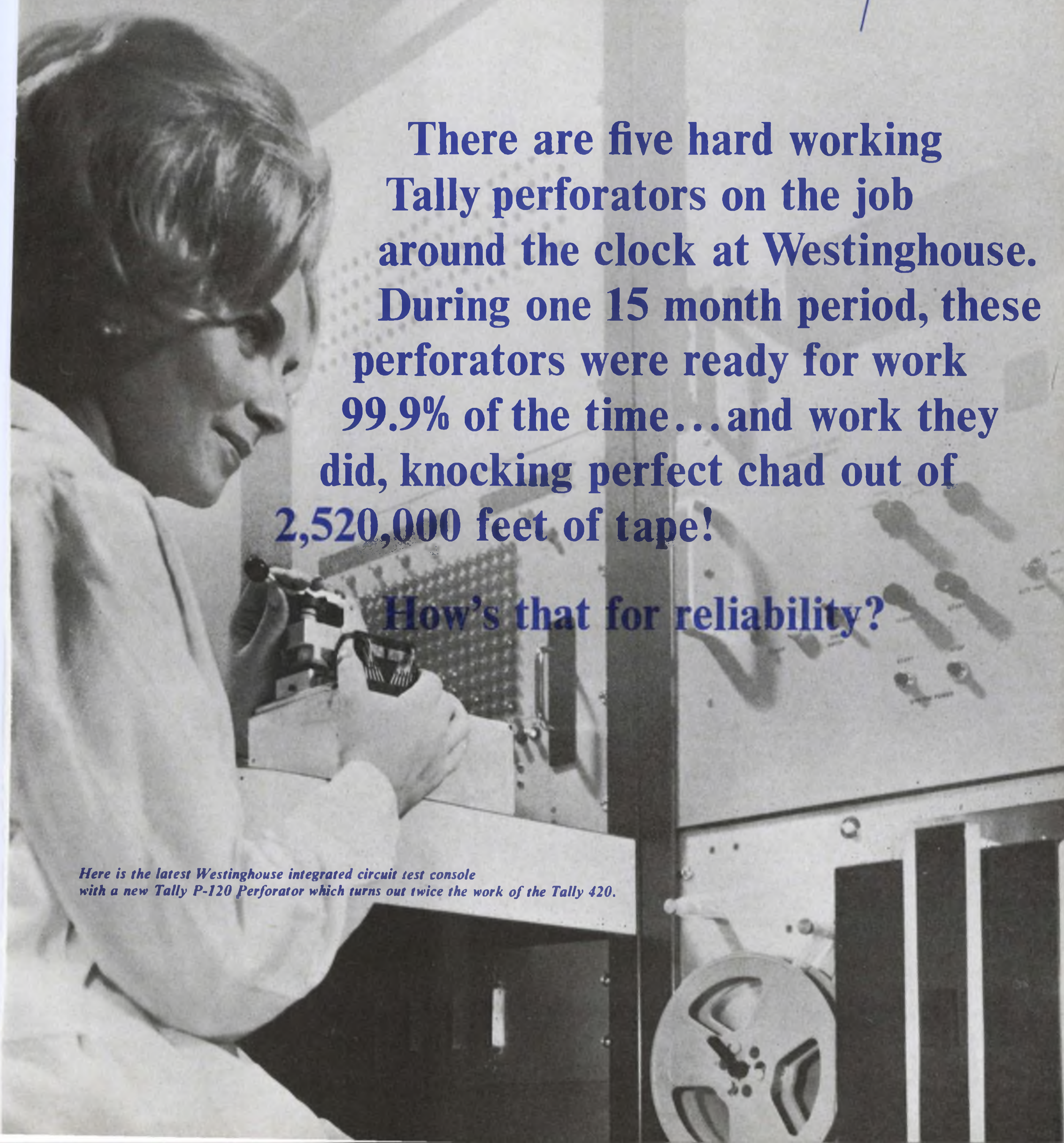
Initially, assume the input voltage is high (1 V is used for illustration). *Q1* and *Q3* are ON and *Q2* is OFF; thus V_o is low. When V_i switches to the low state (at t_i in timing diagram) *Q1* and *Q3* turn OFF, and V_o immediately goes high, since both *Q2* and *Q3* are now OFF. Capacitor *C* starts to charge through R_{c1}. When the voltage across *C* reaches V_t, the turn-on voltage for *Q2*, *Q2* turns

Testing integrated circuits is a key step in their production. At the Molecular Electronics Division of Westinghouse Electric Corporation, Tally perforators are used to log data as each module is run through a series of parameter checks. Data logged on the tape is then analyzed by computer.

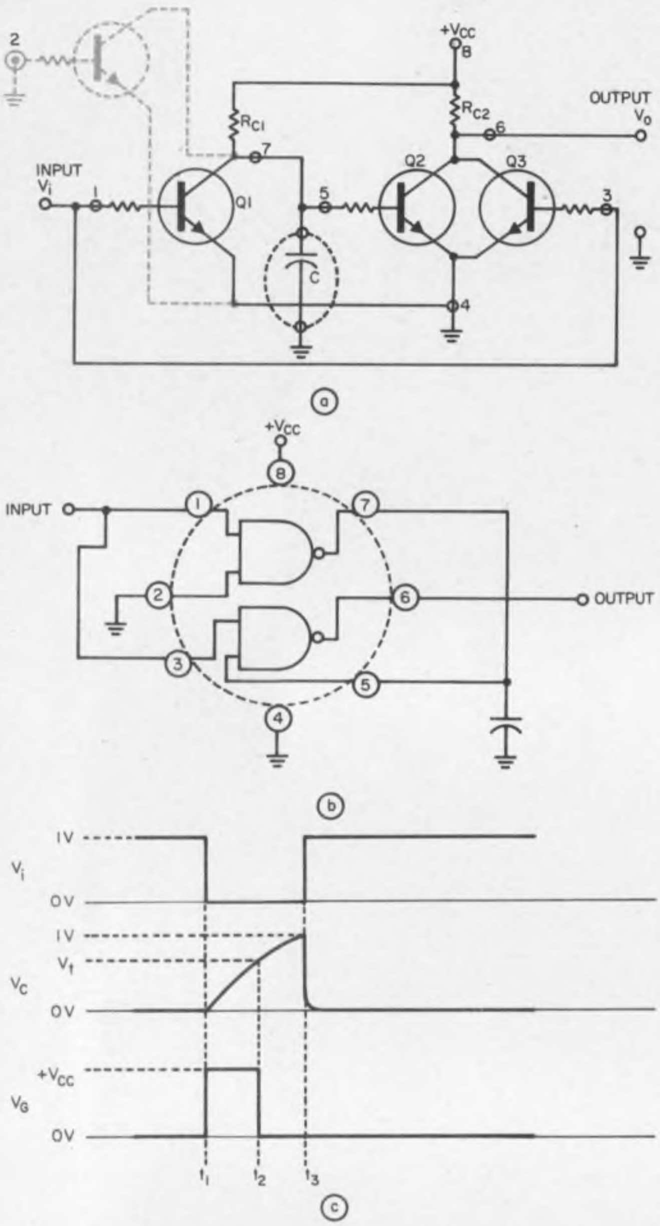
According to W. DeLauder, Foreman of the Instrumentation Section at Westinghouse, the five Tally Model 420 perforators worked extremely well during a fifteen month period just ended. Fewer than eight calls per perforator were made to keep all five perforators on duty over the entire period. The average time per call was 2.23 hours with an average cost for parts of $3.05.

During the fifteen month period, the five perforators punched with precision over 478 miles of tape. There are a lot of good solid engineering reasons why Tally perforators are extraordinarily reliable. For all of them, please address Ken Crawford, Tally Corporation, 1310 Mercer Street, Seattle, Washington 98109. In the U.K. and Europe, address Tally Europe, Ltd., Radnor House, 1272 London Road, London, S.W. 16, England.

TALLY



Here is the latest Westinghouse integrated circuit test console with a new Tally P-120 Perforator which turns out twice the work of the Tally 420.



RTL microcircuit, with the addition of a capacitor (dotted loop), produces a pulse of period $t_2 - t_1$ when the input voltage shifts from a high to a low state. An RTL block (top) is connected as shown below with the pin 2 input grounded.

ON and V_o returns to the low state. At some time later, when V_i returns to the high state, *Q1* and *Q3* will be turned ON again, capacitor *C* will discharge, *Q2* will turn OFF, and the circuit will be ready to repeat operation.

The pulse period depends on the time constant, CR_{c1}, and can be set according to the choice for *C*. Also, t_3 must be greater than t_2.

If two such circuits are cascaded, the result is a pulse delayed in time from t_1 by $t_2 - t_1$. This might be useful to avoid time race or to establish settling times in analog circuitry.

Robert H. Katzive, Design Engineer, Varian Associates, Palo Alto, Calif. VOTE FOR 111

Simple circuit multiplies frequency up to 40 times

High-order frequency multiplication can be quite a problem at low frequencies, say below 5 kHz, because inductors and capacitors become bulky and unwieldy, especially if high *Q*s are needed.

A conventional *Q* multiplier circuit is the designer's answer. The circuit shown can efficiently multiply the frequency 40 times or more with very little envelope decay. Hence the output can be amplified with a little filtering for clean waveshapes.

Normally such circuits are used to obtain greater selectivity by multiplying the *Q* of a tank circuit and narrowing the bandwidth. The frequency multiplication is best illustrated with an example. Assume that the 20th or greater harmonic of a 1-kHz signal is needed. *L1* is selected from a catalog to have a high *Q* at 20 kHz. Then *C1* is selected to resonate with *L1* at the desired frequency, according to the equation:

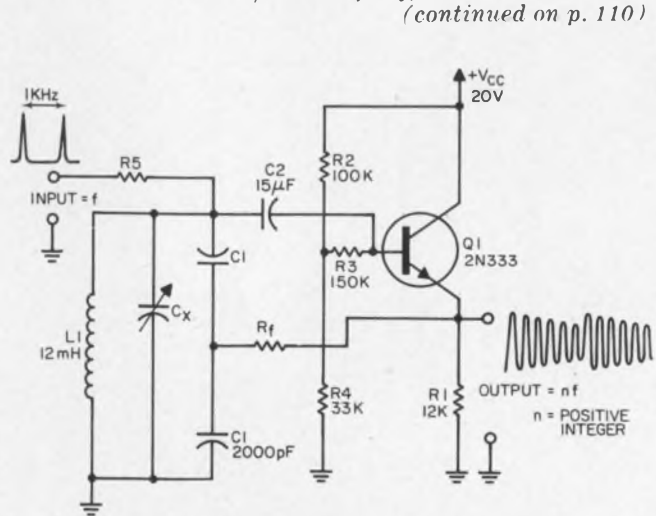
$$C1 = 1/L(2\pi f)^2, \qquad (1)$$

where f is the multiplied frequency (Hz).

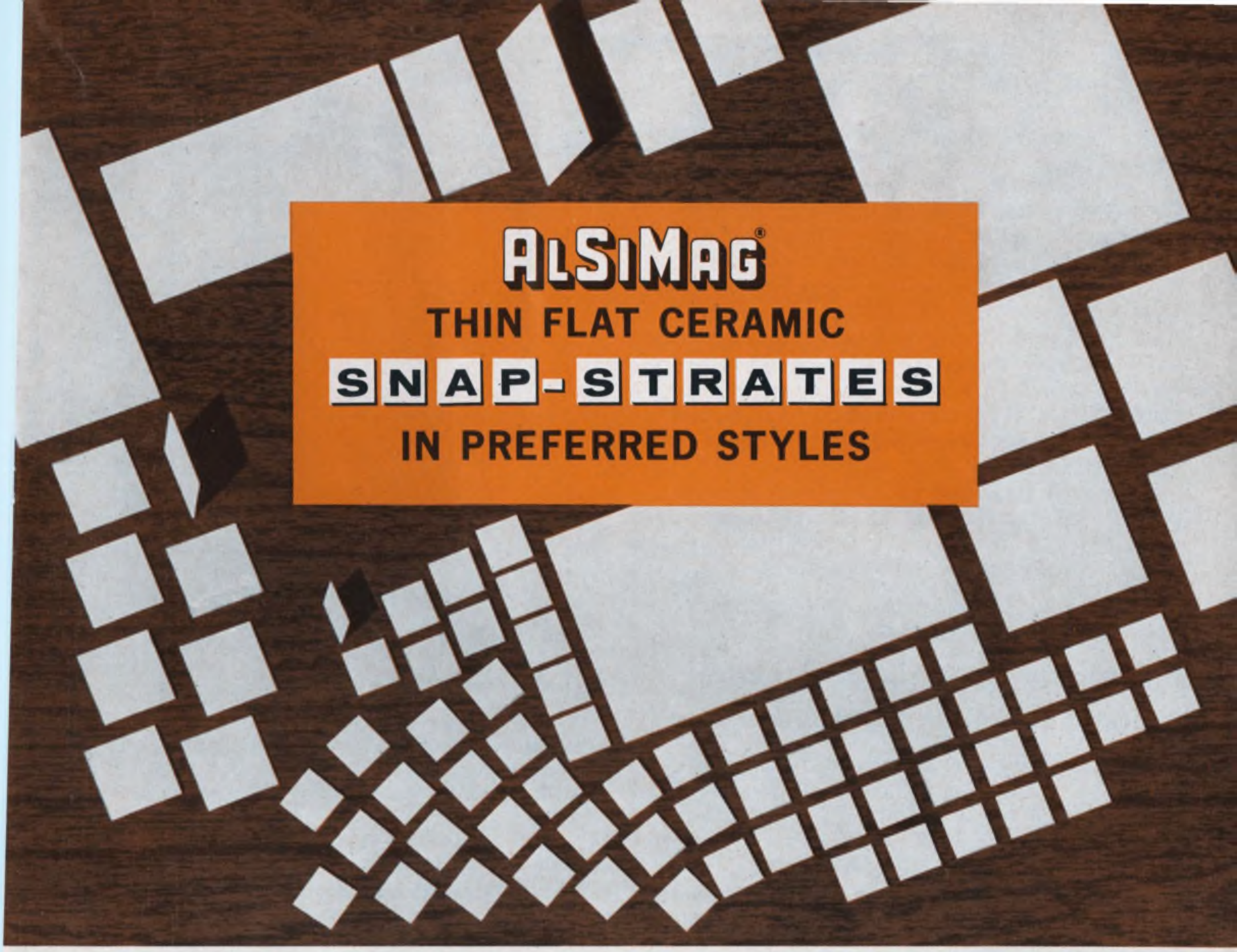
The value of resistor R_f should be below that required for oscillation. It may be a potentiometer, for maximum selectivity, or a fixed resistor. The feedback voltage through R_f is enough to compensate for the losses inherent in the tank circuit. Hence R_f can be adjusted to the point where the circuit will oscillate at frequency f. Any value below this initial value will increase the *Q* of the tank. If it is assumed that the input impedance of the emitter follower stage *Q1* is infinite and there is no loading on the tank, the critical value of R_f is:

$$R_f = 0.5\,\pi f L Q,$$

(continued on p. 110)



Conventional Q multiplier circuit performs efficient high-order frequency multiplication.



Substantial production economies may result from monolithic but separable alumina ceramic substrates as pioneered and developed by American Lava. The user snaps the parent part into individual substrates AFTER all film and circuit work is completed.

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Tooling is presently available for preferred style Snap-Strates in a thickness of .020" in these sizes:

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Snap-Strate AlSiMag 614 1" x 2" yielding eight ½" x ½"

Snap-Strate AlSiMag 772 2" x 2" yielding four 1" x 1"

Snap-Strate AlSiMag 772 1½" x 2½" yielding sixty ¼" x ¼"

The tooling is interchangeable between AlSiMag 614 and AlSiMag 772 if a slight difference in size is not critical.

As new requirements in volume are established, Snap-Strates will be made available to meet these new needs. If you have special requirements, we will be glad to make Snap-Strates to your blueprint or to work with you to find the most economical design.

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where Q=loaded Q of the coil and f=multiplied frequency.

The emitter-follower stage is designed for Class-A operation. *R3* should be as large as possible to avoid loading the tank with the parallel combination of *R2* and *R4*, and the transistor input impedance. The input wave can be a sawtooth, or pulse wave with high harmonic content. This is fed to the base circuit of *Q1* through resistor *R5*, which is also selected so as not to load the tank circuit. A capacitor C_x can be inserted across *L1* to obtain exact tuning to the desired harmonic and can also serve to tune to higher or lower harmonics.

The circuit performed good frequency multiplication of 1 kHz up to 40 kHz at temperatures above 60°C.

A. L. Plevy, Designer, East Brunswick, N. J.

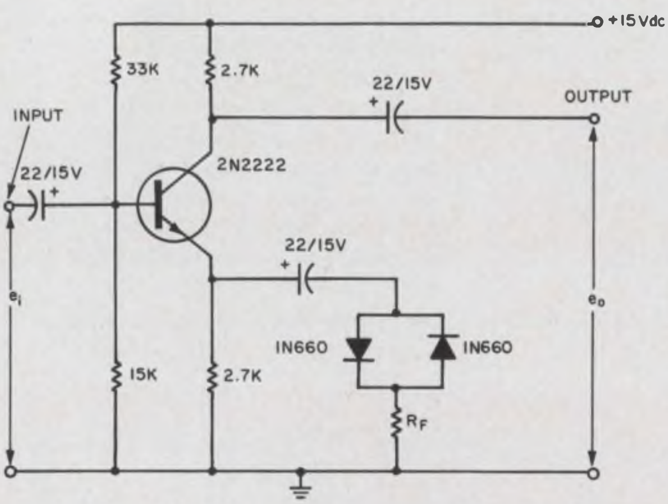
VOTE FOR 112

For higher gain, diode network reduces negative feedback

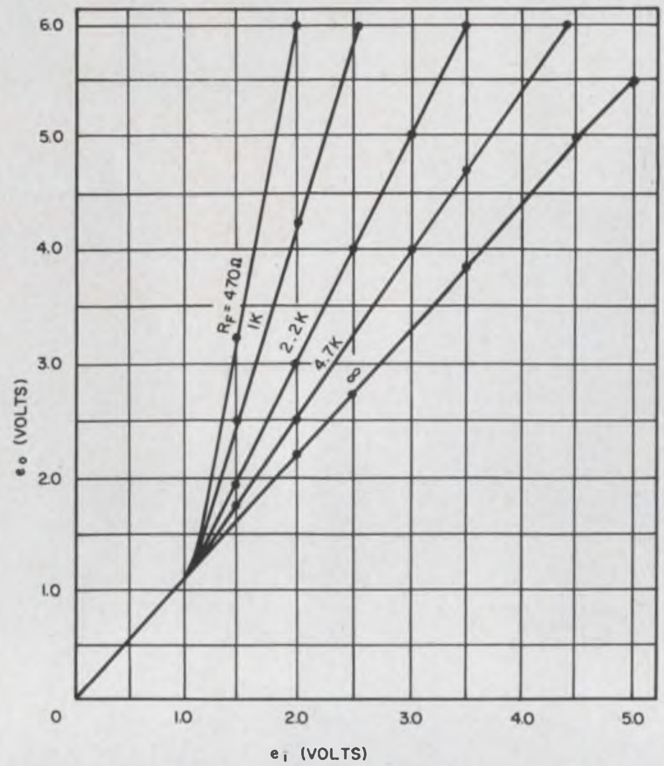
If the gain of an amplifier is increased as the signal level increases, it will linearize transducers' nonlinear outputs and enhance selected portions of a video signal.

The inclusion of two diodes in the emitter feedback loop (Fig. 1) helps to reduce the negative feedback. This leads to an increase in stage gain.

The diodes are biased into conduction whenever the signal excursions at the emitter reach a certain amplitude (about 0.9 V p-p). Then R_F, in parallel with the emitter resistor, reduces the negative feedback. The signal level at which this nonlinearity occurs may be increased by the inclusion of more than one diode in each leg of the parallel feedback network. As shown in the plot of the transfer characteristics (Fig. 2), the gain above the break point may be adjusted by varying the value of R_F.



1. **Gain of nonlinear amplifier** increases with increasing signal levels because of the diodes in its emitter feedback loop.



2. **The transfer characteristics** of the amplifier may be adjusted by varying R_F. The diodes are biased into conduction at the break point of 1 volt.

If the diodes are placed in the collector-to-base feedback network, the gain will be reduced (see "Complementary diode feedback produces nonlinear gain," ELECTRONIC DESIGN, XIII, No. 12 (June 7, 1965), p. 42).

Jack K. Hickman, Engineer, Texas Instruments, Inc., Apparatus Div., Dallas.

VOTE FOR 113

Synchronized one-shot built with three SCRs

A useful, synchronized one-shot can easily be built with silicon-controlled rectifiers.

Operation of the circuit (see figure) is as follows: Assume that the line voltage has been connected for some length of time and the reset button *S2* has been activated. Then *SCR2* is the only SCR conducting. During the positive half cycle *SCR2* conducts through paths *R2 – D9 – SCR2* and *D7 – R1 – SCR2*, and *C1* charges through *S1 – D11 – C1 – R5*. During the negative half cycle, *SCR2* is

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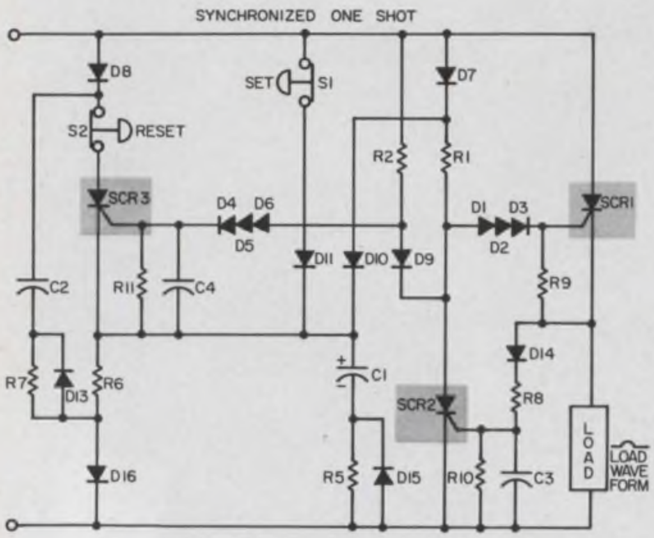


SCRs are used to build a synchronous one-shot useful for dispensing-system and electric welding applications.

held in conduction by capacitor *C1*'s discharging through path *D10 – R1 – SCR2 – D15*.

The time constant *R1 – C1* must be chosen such that a discharge current greater than the holding current of *SCR2* flows for more than one half cycle but less than two half cycles. *R5* is chosen such that it safely limits the charging current of *C1* during the positive half cycle through *S1 – D11 – C1 – R5*. *SCR1* and *SCR3* are prevented from triggering into conduction by the IR drop across *R1* and *R2* and by the fact that the series combinations of diodes *D1 – D2 – D3* and *D4 – D5 – D6* combine to form a junction whose breakdown is higher than the voltage drop across *SCR2*.

If set button *S1* is depressed, *C1* is no longer charged during the positive half cycle. *C1* will discharge such that, at the beginning of the next positive half cycle, *SCR2* will be OFF and *SCR1* will be triggered through path *D7 – R1 – D1 – D2 – D3* to its gate. Similarly *SCR3* will be triggered through *R2 – D6 – D5 – D4* to its gate, but later than *SCR1*, since *R2* must first charge *C4* to *SCR3*'s gate breakdown voltage. When *SCR1* began conducting, a delayed triggering path (*SCR1 – D14 – R8*) for *SCR2* was established. *R8* and *C3* must be chosen such that *SCR2* will always be triggered ON after *SCR3* for proper operation.

When *SCR3* conducts, it functions as an *S1* bypass which will supply a charging path for *C1* (*D8 – S2 – SCR3 – D12 – C1 – R5*), regardless of how many cycles the operator holds *S1* open. *SCR3* locks in by virtue of *C2*'s being charged during the positive half cycle through path *D8 – C2 – R7 – D16*; during the negative half cycle, *C2* discharges through *S2 – SCR3 – R6 – D13*, maintaining *SCR3* in conduction till the next positive half cycle. *SCR1* conducts until the line reverses on it and it resumes its blocking state. In the following positive half cycle, *SCR1* is prevented from triggering ON by *SCR2* as described earlier. *SCR1* then conducts synchronously for a complete half cycle and provides the operation expected of it.

The circuit has potential application in several areas such as electric welding or industrial dispensing systems.

Alexander Prokop, Research Dept., Skil Corp., Chicago, Ill.

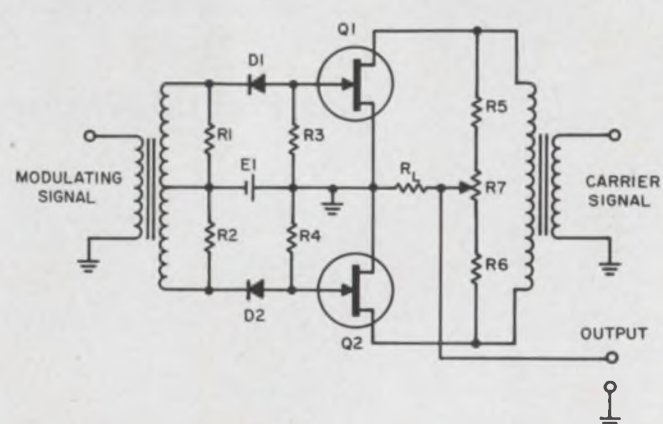
VOTE FOR 114

FETs in balanced modulators improve linearity and band

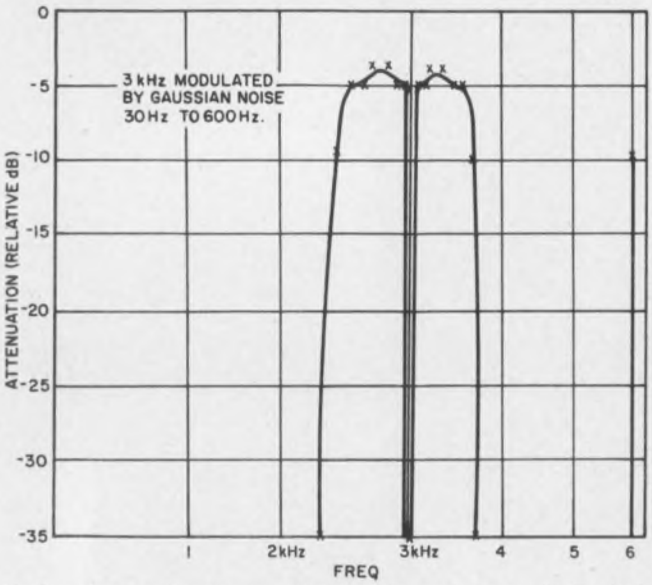
A balanced modulator made with field-effect transistors offers the best trade-off among conventional modulator types. It consumes less power than tube types, is less expensive than diode types and has a broader band than both the saturating and mechanical switching types. It is more linear than most bipolar transistor modulators, and its high degree of harmonic rejection eliminates the need for the filters used in switching modulators.

Almost any standard balanced-modulator application can be met with the circuit shown in Fig. 1, so long as the power and frequency limitations of the FETs are not exceeded.

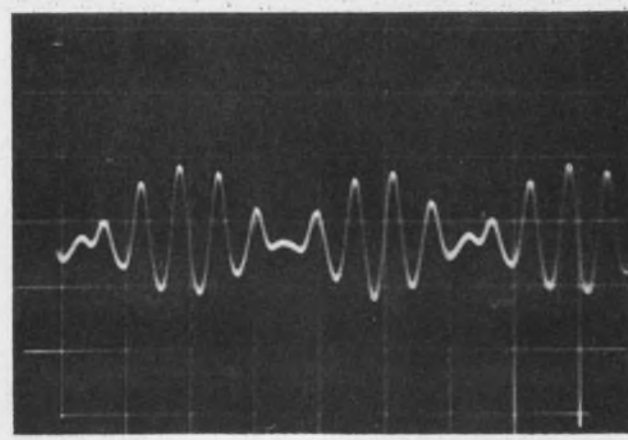
The bridge is initially balanced with *R7* to give a minimum output signal with the modulating signal input grounded. During most of one half cycle of the modulating signal, diode *D1* is back-biased, and the gate of *Q1* is grounded through *R3* (typically about 1 M). This turns *Q1* on. At the same time the resistance of *Q2* is being modulated by the gate voltage, unbalancing the bridge to change the carrier level. During the other half



1. **FET balanced modulator gives 180° zero-crossing phase shifts** as the resistances of Q2 and Q1 are modulated during the first and second half cycles, respectively.



2. **Spectrum of noise-modulated signal** is essentially flat from $f_c - f_1$ to $f_c + f_1$ with a hole at f_c. The swept-frequency bandwidth is 10 cps.



3. **Typical output waveform** shows the modulation of 3-kHz signal by a 300-Hz one. The vertical scale is -50 mV/cm, and the horizontal, 500 μsec/cm.

cycle of the modulating signal, *Q2* is on and the bridge is unbalanced in the opposite direction. The 180° zero-crossing phase shift results, characteristic of a balanced modulator. *E1* biases the gates of the FETs slightly down, improving linearity during the time when the modulating signal is near zero, much like the biasing circuitry of a class-AB amplifier. A good value for *E1* is 5 to 10% of V_p. *R1* and *R2* minimize the effects of nonlinear transformer loading; they should therefore be much smaller than *R3* and *R4*.

The FETs should be matched for g_m or r_{on} and v_p. The modulating signal level should be kept small enough so that the FET's transfer function is approximately linear. If greater linearity is desired, a nonlinear function generator may be inserted in the gate lead to compensate for the nonlinearity of the FET transfer function. The transformers can, of course, be replaced with active phase splitters and suitable isolating capacitors, if the designer wishes.

The circuit values are noncritical and will vary with the FETs and transformers used, but here is a sample set:

R5 + *R6* + *R7* should be about equal to 20 r_{on} of the chosen FET; so for a 2N4303, $R5 = R6 = 3.3$ kΩ and $R7 = 5$ kΩ. R_L should not load the bridge severely—27 kΩ is a good value. $R3 = R4 = 1$ MΩ. D1 = D2 = any silicon signal diode (for silicon FETs), for example, 1N461. $E1 = 1/2$ V with the 2N4303s. $R1 = R2$, and these should be selected to match the transformer, or vice-versa, but they should not be so large that 1 MΩ will provide significant loading. To conserve modulating power, values as high as 68 kΩ may be used for audio-frequency work.

Of course, system constraints,—such as input and output impedance, required frequency range, etc.—must be considered in the selection of element values and transistors.

The carrier rejection of the circuit is greater than 35 dB, as is the second harmonic rejection. Linearity in the 1-2% region can be obtained without function generators if signal levels are kept low and the FETs and diodes are fairly closely matched. Extremely close matching is not required—about 5% for r_{on} and 10% for V_p.

The unit is broadband with respect to both the carrier and the modulating signal, which is a distinct advantage over a class-C balanced modulator in many applications.

If the modulating signal is noise that has been passed through a low-pass filter with cut-off frequency f_1, and the carrier frequency is f_c, the resultant spectrum (Fig. 2) will be essentially flat from $f_c - f_1$ to $f_c + f_1$ (with a hole at f_c). This flatness is a result of the modulator's carrier-rejection properties. The band of noise may be varied in frequency by varying f_c.

A typical output waveform of a 3-kHz sinusoidal signal modulated by a 300-Hz signal is shown in Fig. 3.

James M. Kasson and John L. Stewart, Research Associates, Santa Rita Technology, Inc., Menlo Park, Calif.

VOTE FOR 115

IFD Winners for Aug. 30, 1966.

Gilbert Marosi and Neal Vinson, Design Engineers, Link Group, General Precision, Inc., Sunnyvale, Calif.

Their Idea, "Extra transistor gives Schmitt monostable multi capabilities," has been voted the $50 Most Valuable of Issue Award.

Cast Your Vote for the Best Idea in this Issue.

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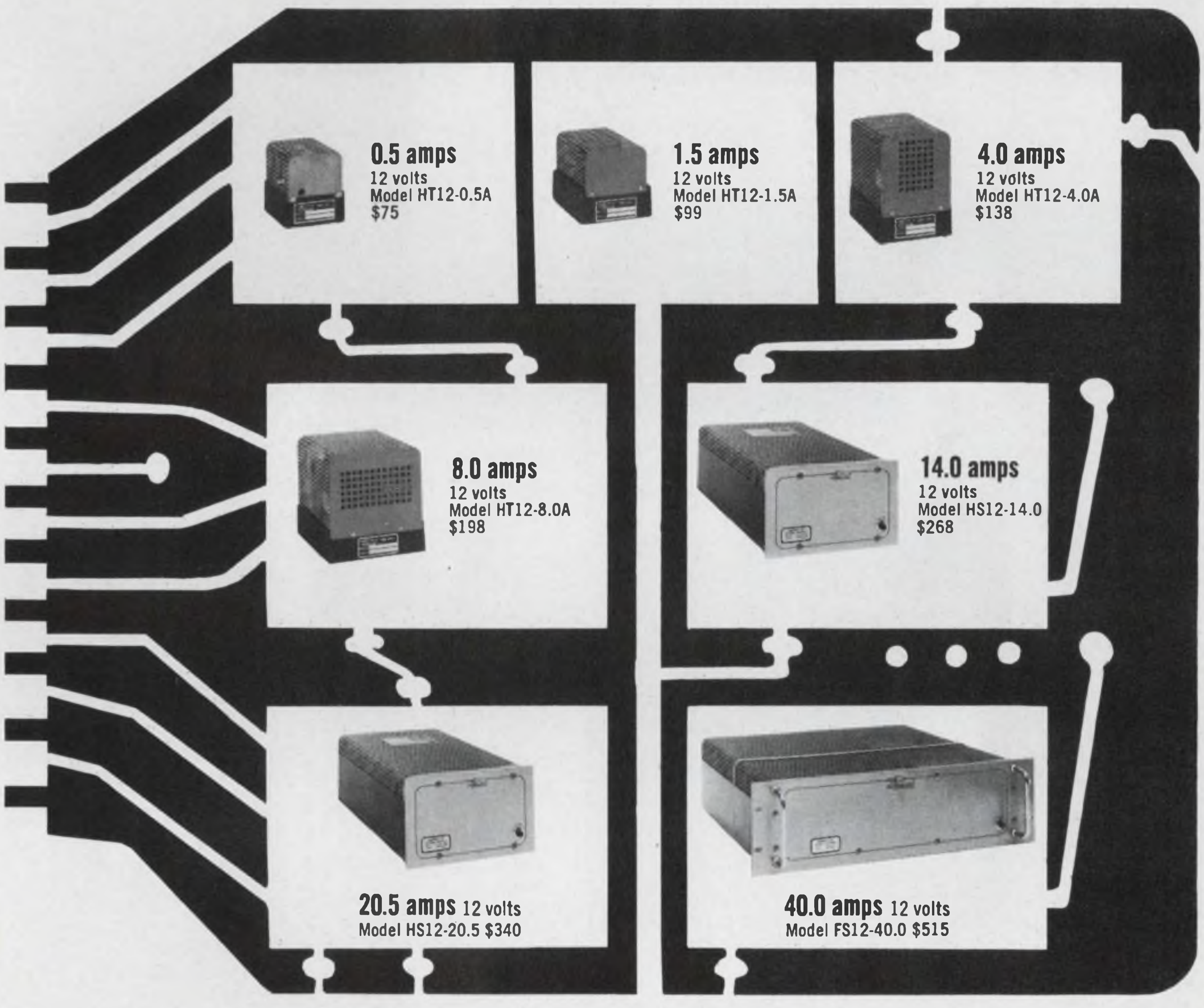
Now available in any current to 40 amps.



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The modules shown on this page, designed specifically for logic card systems, are just part of Con Avionics' line of power supplies. Those shown all operate at 12 volts. (We make just as many at 3, 6, 18 or any other logic card voltage.) The modules have a combined line and load regulation of $\pm 0.05\%$.

Like all Con Avionics power supplies, these are unconditionally guaranteed for five years. Models with a current rating below 10 amps have a typical M.T.B.F. of 100,000 hours. Others have an M.T.B.F. of 35,000 hours.

You'll find Con Avionics supplies for relay applications, IC systems, or any systems requirement, all listed and priced in our Catalog 66A. For your copy, circle card, or write, call or TWX Mr. Gerry Albers.

ON READER-SERVICE CARD CIRCLE 54

Here's the first AC-powered, high sensitivity Null Detector that won't upset circuit balance!

New Honeywell 3990 with True Differential Input

The new Honeywell 3990 Null Detector's true differential, symmetrical input permits AC operation while providing isolation and common mode rejection comparable to similar battery powered units. When reversing polarity, absolutely no Zero Offset is experienced. A wide performance range is assured by sensitivity of better than 20 nanovolts, with seven full scale ranges from ±0.1 microvolts to ±100.0 millivolts. And, the new 3990's high input impedance allows its use with source impedances or unbalance as high as 6000 ohms without degradation of performance.

The Honeywell 3990 eliminates these common measurement problems:

- False balance when reversing polarity
- Inaccuracies due to ground loops
- Large decrease in sensitivity due to high source impedances
- High noise levels due to high source impedances
- Stray noise pickup
- Poor common mode rejection on AC operation

These features make the 3990 the most versatile Null Detector you've ever used:

- Failsafe operation with excessive input overload
- AC operation – no battery replacement
- Chopper stabilized operational amplifier assures excellent stability
- High CMR; greater than 160 db @ 60 Hz
- Expanded scale meter for greater resolution
- Grounded recorder output, completely isolated from input.
- Available as bench or rack-mounted model

All these outstanding features, yet the new 3990 is as easy to use as a galvanometer and you don't have to worry about vibration! For complete information, contact your Honeywell Representative, or mail the coupon for fully illustrated literature.

LABORATORY STANDARDS

Honeywell

Carl Boyer
Mail Station 12-12A
Honeywell Test Instruments Division
Denver, Colorado 80217

Please send Model 3990 Null Detector literature to:

Name________________

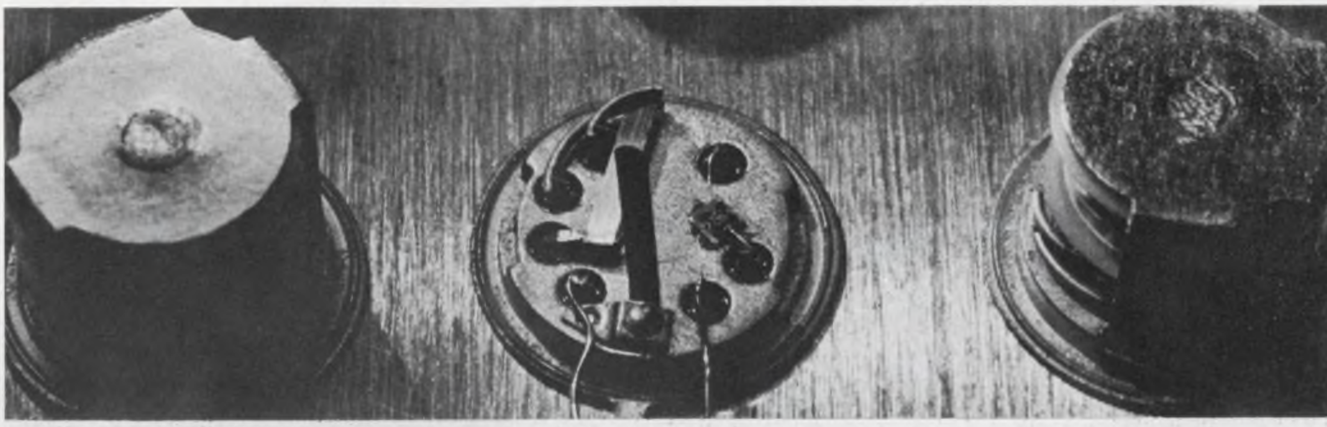
Company________________

Address________________

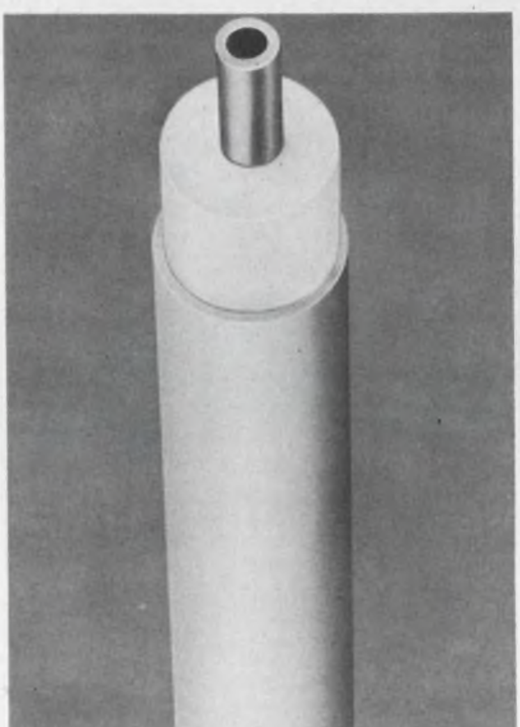
City________ State________ Zip________

ON READER-SERVICE CARD CIRCLE 55

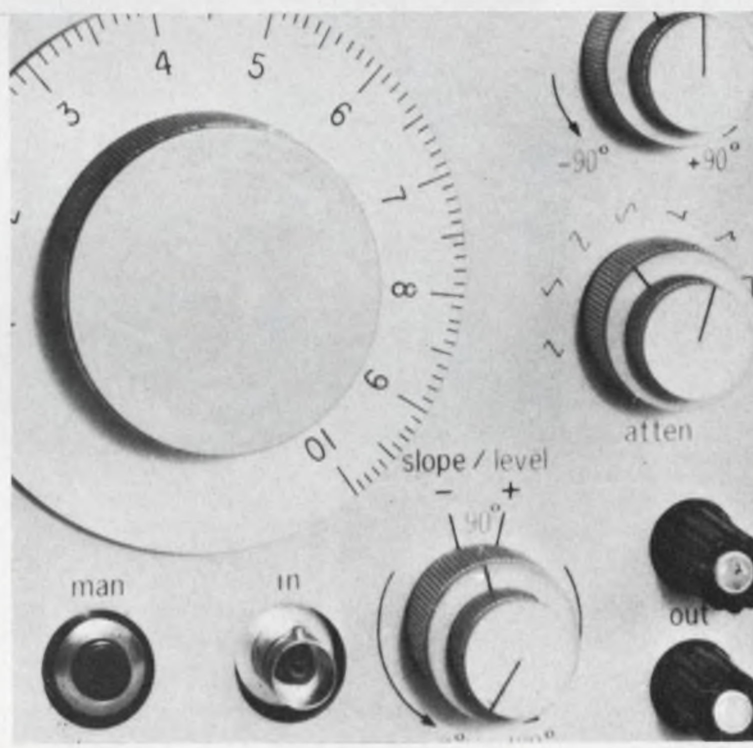
Products



A relay and a FET in a TO-5 can? For operation off low-level micrologic, this spdt relay has its own integral solid-state amplifier. Strange partners in a TO-5 can? Page 118.



Low-loss cable uses foam dielectric, tubular outer conductor. Page 156.



Portable function generators operate triple-mode—triggered, gated or phase-locked. Page 144.

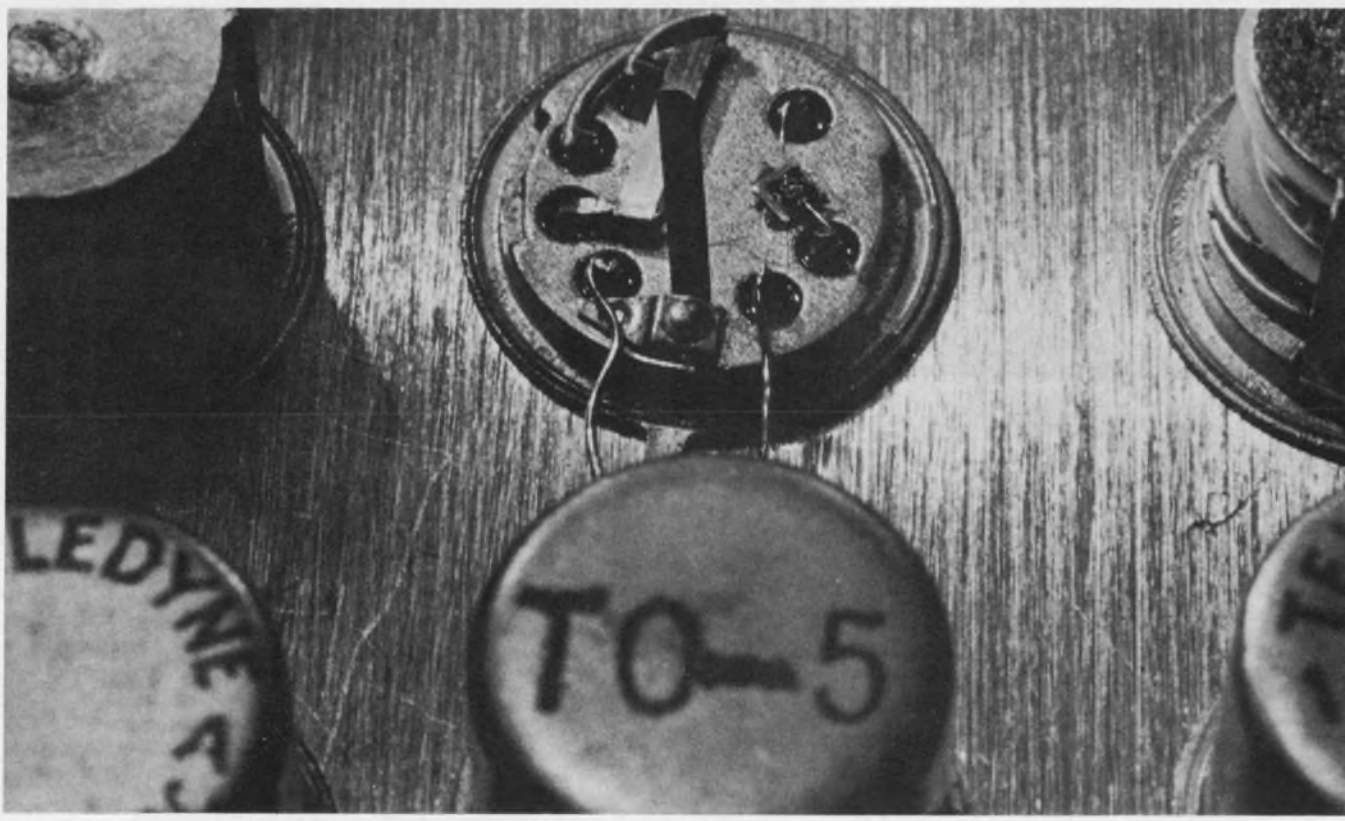
Also in this section:

Tiny inductors are tuned from the top. Page 122.

Submin silicon diodes lose their whiskers. Page 152.

Unijunction transistors for long time-delay circuit design. Page 153.

FET amplifier and relay in a TO-5 can operates directly off low-level microcuitry

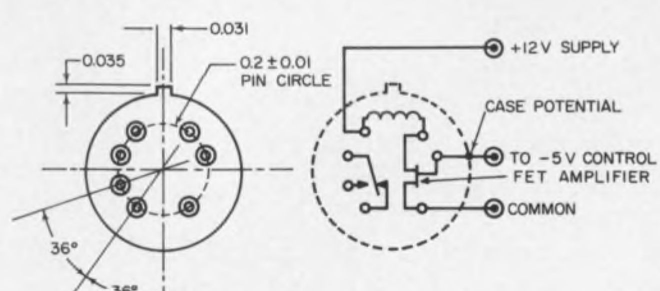


Teledyne Precision, Inc., 3155 El Segundo Blvd., Hawthorne, Calif. Phone: (213) 679-2205. P & A: $29.85 (1 to 99), $22.50 (500) for FET, $27.90 (1 to 99), $20.90 (500) for bipolar; 6 wks.

Proponents of solid-state technology have been declaring the mechanical relay passé. Opponents, on the other hand, say that relays have isolation and environmental advantages that solid-state switching devices cannot match. Teledyne Precision, Inc., has paused long enough in the scuffle to combine the best of the two technologies: it has put its TO-5 relay and a FET or bipolar transistor amplifier in the same TO-5 can.

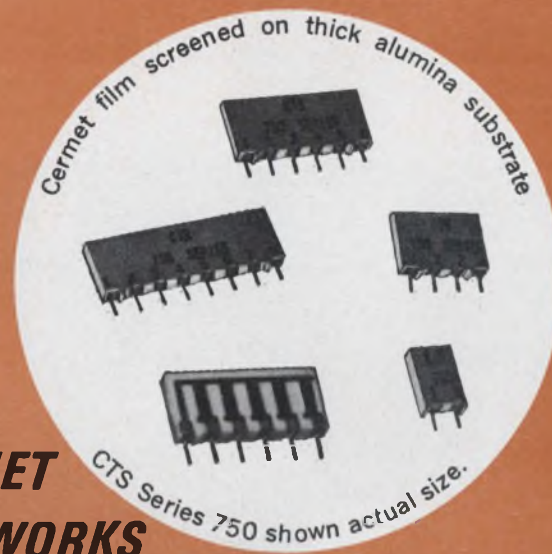
Formerly the circuit engineer could design in a relay that would be tripped directly (requiring a comparatively large amount of current). Or he could use a transistor in conjunction with the relay to reduce the amount of current needed for activation. The new Teledyne line provides the relay and amplifying device inside the standard TO-5, so that, for the same space and weight, the designer has a relay that requires only tiny drive currents for operation directly off low-level logic circuits.

Two devices are being introduced. The relay-FET amplifier requires only nanoamps to trip the relay. The relay-bipolar transistor amplifier offers



Spdt relay and FET driver are mounted in standard TO-5 can. Supply voltage is 12 Vdc nominal and relay coil is rated at 500 Ω.

NEW LOWER PRICES



NEW TEST DATA FOR CTS INDESTRUCTIBLE CERMET SEMI-PRECISION RESISTOR NETWORKS

Series 750	2-Pin (1 Resistor)	4-Pin (3 Resistors)	6-Pin (5 Resistors)	8-Pin (7 Resistors)
Total Module Load	0.5 Watts	1.0 Watts	1.5 Watts	2.0 Watts
Approx. 10,000 cost	20¢ ~~$0.22 ea.~~	21¢ ~~$0.24 ea.~~	23¢ ~~$0.26 ea.~~	29¢ ~~$0.31 ea.~~
Approx. 100,000 cost	18¢ ~~$0.20 ea.~~	19¢ ~~$0.22 ea.~~	21¢ ~~$0.24 ea.~~	26¢ ~~$0.28 ea.~~

The data speaks for itself. Examine and judge its value for your application:

Extreme Stability and Reliability
High Power Capability: (Up to 1 watt per resistor)

- **Space saving—a single module replaces up to 7 discrete resistors.**
- **Available in an infinite number of circuit combinations.**
- **Custom-built to your exact requirement.**
- **Ideally suited for cost-saving automatic handling.**
- **Cover coating unaffected by solvents.**

STANDARD MODULE SPECIFICATIONS FOR ALL SIZES	
Resistance Range	50 Ω to 100K Ω
Resistive Tolerance	±5.0%
TC	±300 ppm/°C
Load Life: 0.1 W per resistor at 70°C, 1000 hrs. (Over 4,000,000 resistor hours)	±0.40% Δ R max. ±0.20% Δ R av.
Moisture Resistance: .1 rated wattage at 70°C, 90-98% humidity, 1000 hrs.	±0.50% Δ R max. ±0.20% Δ R av.
Insulation Resistance: measured wet after moisture resistance test, 200 VDC	500 meg. Ω
Thermal Shock: 5 cycles, −63°C to +125°C, no load	±0.10% Δ R max. ±0.03% Δ R av.
Short Time Overload: 2.5 times rated voltage, 5 sec.	±0.25% Δ R max. ±0.05% Δ R av.
Low Temperature Exposure: −63°C, 4 hrs.	±0.10% Δ R max. ±0.04% Δ R av.
Terminal Strength: 5 lb. tensile & compression, 30 sec.	±0.10% Δ R max. ±0.03% Δ R av.
Effect of Soldering: 63/37 solder, 246°C, 2 sec.	±0.10% Δ R max. ±0.05% Δ R av.

founded 1896

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Extra cost options	
Resistance Range	10 to 49 Ω, 101K to 1 meg. Ω
Resistive Tolerance	±0.5%, 1%, 2.5%
TC	±150 ppm/°C

ON READER-SERVICE CARD CIRCLE 56

Component characteristics

FET (Amelco U1526)

$BV_{(DS)} = 40$ V ($V_{DS} = 0$, $I_D = 0.001$ mA)
$I_{DSS} = 20$ mA ($V_{DS} = 20$ V, $V_{GS} = 0$)
I_{DGO}, $I_{SGO} = 1$nA ($V_{DG} = 25$ V, $I_S = 0$)
I_D (off) $= 1$ nA ($V_{DS} = 20$ V, $V_{GS} = 11$ V)
$V_p = 2$ to 10 V ($V_{DS} = 20$ V, $I_D = 10$ nA)
R_{DS} (on) $= 100\ \Omega$ ($V_{GS} = 0$, $I_D = 1$ mA)

Bipolar transistor (Amelco A1341)

$h_{FE} = 50$
$P_c = 200$ mW
$V_{CBO} = 75$ V
$T_j = 150°$C
$I_{co} = 0.01\ \mu$A

Relay

Contacts: 1 Form C (spdt)
Contact rating: low-level to 1 A, 28 Vdc
Contact resistance: 0.1 to 0.2 Ω
Life: 10^5 cycles at 1 A, 10[illegible] cycles at low-level
Insulation resistance: 10,000 MΩ at 500 Vdc
Operate time: 2 ms max
Contact bounce: 1.5 ms max

the same benefits in those cases where the FET's input impedance is not a consideration. Prices here are slightly lower.

The relay itself, which Teledyne believes to be the world's smallest, has been available in the TO-5 can for about two years. It is rated at 1-A 28-Vdc resistive in an spdt contact arrangement. Supply voltage is 12 Vdc and load resistance (coil) is 500 Ω $\pm 10\%$. Initial contact resistance is 1 Ω, increasing to a maximum of 2 Ω. The operating time is 2 ms.

The addition of the chip inside the same can produces some obvious design benefits: compared with the use of a discrete relay and discrete solid-state amplifier, the new units cut volume in half, reduce weight by the same factor and increase reliability (one header and a whole set of interconnections are eliminated).

The unique package has not compromised TO-5 can or relay reliability either. The devices meet MIL-R-5757 over an ambient range of -65 to 125°C. They withstand 80-G, 11-ms shock and 30-G, 100- to 3000-Hz vibration with no opening of closed contacts in excess of 10 μs.

The solid-state chips are being produced by Teledyne's Amelco Semiconductor Div. The FET, an Amelco U1526, is an n-channel silicon planar device. The bipolar, Amelco A1341, is a general-purpose silicon npn audio amplifier. Specs on the FET, the bipolar and the relay are tabulated in the table above.

CIRCLE NO. 159

equipment shrinker's magic

Quick, Watson, the magnifying glass! You'll need it when you examine this newest addition to Ohmite's family of wire-wound, ceramic rheostats.

The Model C follows the basic, rugged construction of Ohmite's bigger-wattage jobs which have been specified by industry for 35 years. Yet it measures only ½" in diameter, and projects only 15/32" behind the panel.

For its rating, you won't find anything that compares with the Model C rheostat. Specify it for extra design flexibility in equipment miniaturization.

Rating: 7½ watts* at 40°C ambient.

Resistance Values: 10 to 5000 ohms.

Shafts: Standard type; locking-bushing type; also a high-torque shaft which holds its setting under conditions of shock and vibration.

Ohmite . . . World's Largest Selection of Power Rheostats: 7½ to 1000 Watts

******Mounted on metal panel.*

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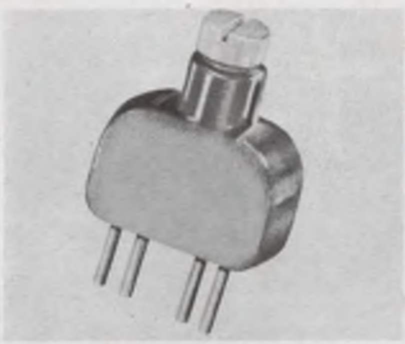
ON READER-SERVICE CARD CIRCLE 58

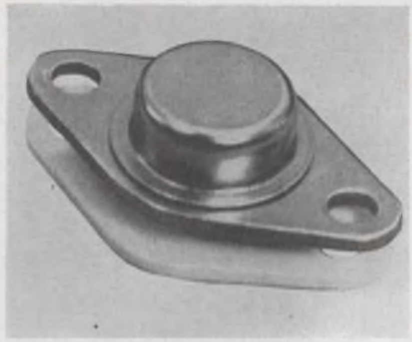


Tiny inductors are tuned from the top

Piconics, Inc., North Billerica, Mass. Phone: (617) 663-4862. P&A: from $9.50; 2 weeks.

Inductances from 0.006 to 5800 μH are available in top-tuning TT inductors that measure 0.280 x 0.97 x 0.450-in. From 2:1 to 10:1 variance ranges are provided depending on the value of the inductance. A stability of 65 ppm/°C is typical. All types of auto transformers, balancing transformers, bifilar transformers, fixed and tunable are available in the design.

CIRCLE NO. 160

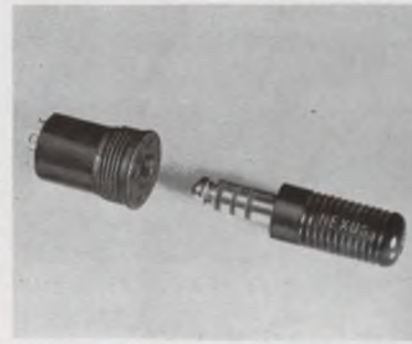


BeO washer insulates TO-66 transistors

Thermalloy Co., 8717 Diplomacy Row, Dallas. Phone: (214) 637-3333.

For insulating many of the newer high-frequency high-voltage transistors, the 4066 washer is designed for TO-66 packages. The beryllium oxide washer is offered as an option to mica or anodized aluminum. Its insulation breakdown is typically 700 V/mil. Heat transfer is comparable to bare aluminum at 140 Btu/hr.ft.°F at 72°F. Typical dielectric constant is 6.

CIRCLE NO. 163

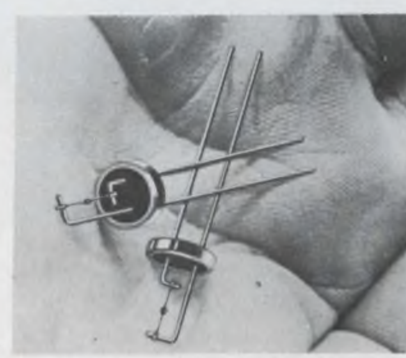


Audio plugs and jacks accept 4 or 5 leads

Nexus Inc., 700 Canal St., Stamford, Conn. Phone: (203) 325-1501.

For intercoms, language labs and similar applications, here is a standard line of small 4- and 5-line plugs and jacks. One-piece contacts eliminate all soldered or welded joints in the line and plug contacts are nickel-plated brass molded into the grey plastic case (DuPont Delrin). Jacks have nickel-plated beryllium grabber contacts and phosphor bronze finger contacts.

CIRCLE NO. 165

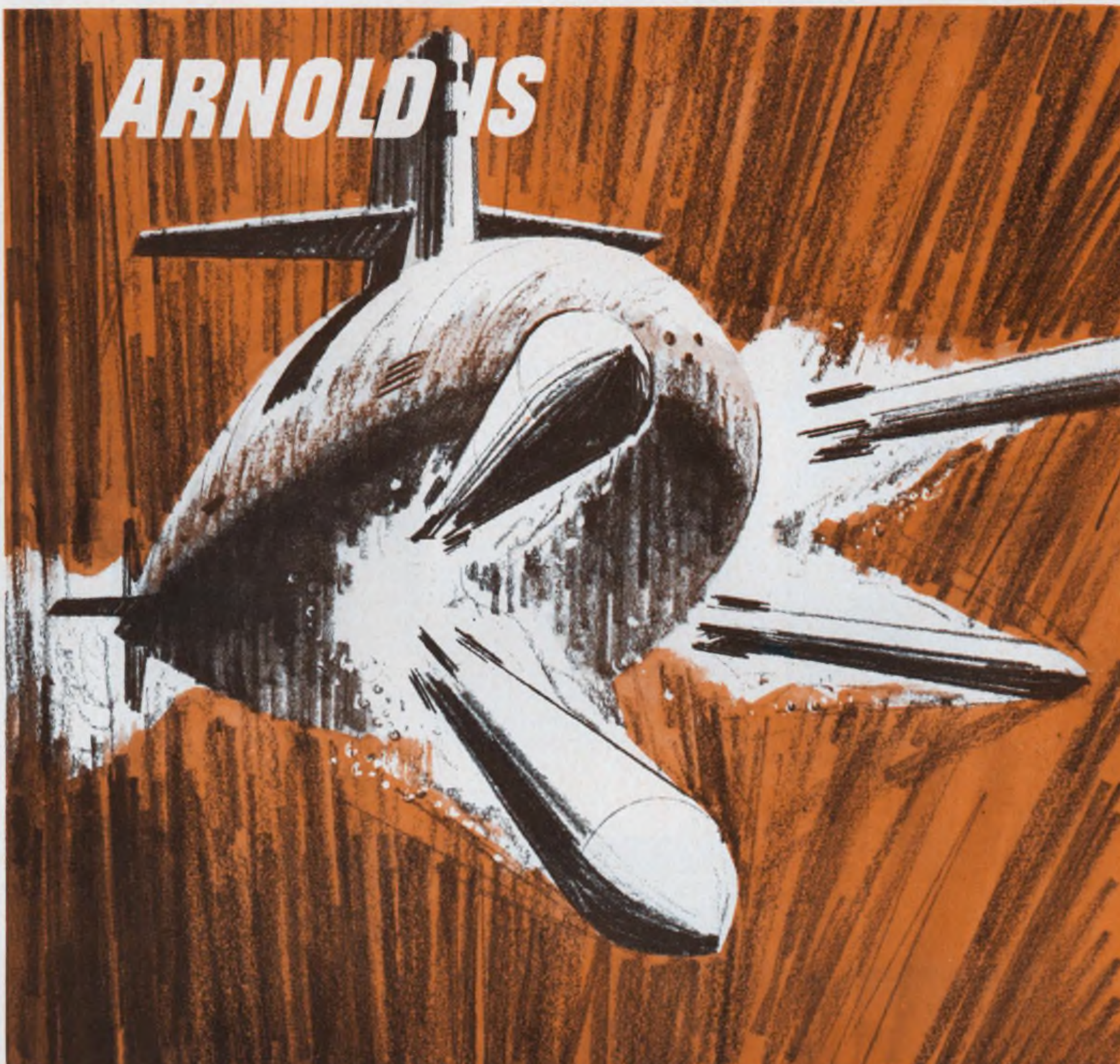


Thermistors matched in current, voltage

Fenwal Electronics, Inc., 63 Fountain St., Framingham, Mass. Phone: (617) 875-1351.

Gas chromatographic equipment and other thermal conductivity gas analysis instruments are among the suggested applications for three voltage-current matched thermistors. The units are revised versions of the manufacturer's G112, G126 and G128 thermistors. A new method of mounting the thermistor bead is said to improve stability and reduce noise.

CIRCLE NO. 161



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Arnold Silectron cores are fabricated from the highest grades of grain-oriented silicon steel. We maintain complete control over all phases of fabrication . . . processing, rolling, slitting, winding, annealing and final test are all "in plant" functions. Many are in stock ready for same day shipment.

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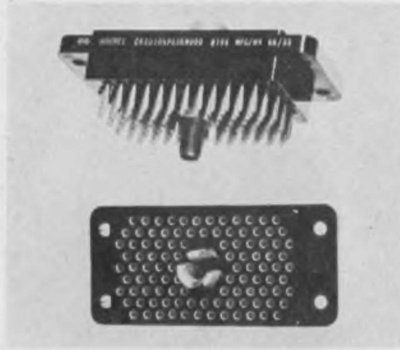
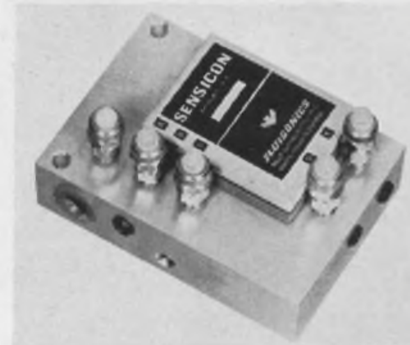


Rectangular connector uses 16-gauge contacts

Hughes Aircraft Co., 500 Superior Ave., Newport Beach, Culver City, Calif. Phone: (714) 548-0671.

A rectangular connector for OEM computer applications uses #16 contacts. It is offered in sizes from 10 to 212 contacts with a maximum contact density of about 50/sq-in. The over-all mated length of the CRS connector ranges from 1.675 to 2.875-in. Components of the 212-contact CRS connector will fit through a mounting hole 2.310 x 2.175-in.

CIRCLE NO. 162



Fluidic devices sense and control

Fluidonics Div., Imperial-Eastman Corp., 6300 W. Howard St., Chicago, Ill. Phone: (312) SP 4-1700.

Circuit-sensing and control is offered by a line of fluidic devices called "Sensicon". The series is compatible with any control system requiring digital pressure output. The initial Sensicon uses an interruptible gap for proximity sensing, providing a digital on-off. The complete line will include devices designed for proximity, interruptible, temperature, noise, light or magnetic sensing.

CIRCLE NO. 164

This is a naked YAES terminal.

We've stripped it to show why Burndy YAES Insulug® terminals are unique.

Once the insulation is off, it's easy to see that this terminal is a one-piece unit. That's a Burndy exclusive. Look closely and you'll see that the seam on the terminal body has been brazed. Another unique Burndy feature. And all YAES terminals are *fully* plated. You won't find any exposed copper edges. In fact, there are no unplated edges where the terminal is separated from the carrier. Look inside the terminal body, too. The surface has been serrated to insure intimate contact.

Additionally, each terminal is marked with the range of wire acceptable. As a double check, the tough, nylon insulation is color-coded to indicate wire size.

Installation is quick and easy with either MS 25037 or MR 8-83 ratchet-controlled hand tools.

Automatic installation tools are available, too. Burndy's Bandolug® equipment, the SME and the SME 10, handles wire ranging from 22 to 10. And they handle them quickly, simply and inexpensively. More so than any other tools.

Burndy YAES terminals meet both the Class I and II requirements of MIL-T-7928 when installed with appropriate tools.

There really is more than meets the eye when it comes to Insulug terminals and tools. Write for Bulletin YAES-66 and see for yourself.

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ON READER-SERVICE CARD CIRCLE 63

COMPONENTS

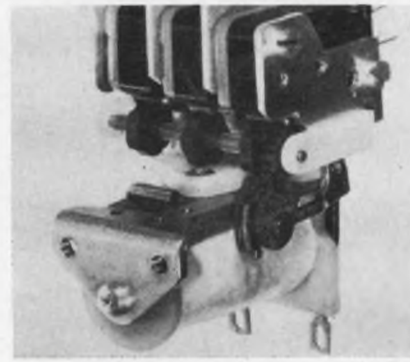
Rotary sampler below 50 microvolts in noise

I.D.M. Electronics Ltd., Arkwright Road, Reading, Berkshire, England. Phone: Reading 82557. Price: from $645.

Extremely long life and very low noise are the leading features of a rotary sampling switch from Britain. Life is specified for 100 million revolutions minimum before servicing and noise is said to be below 50 μV, too low to measure with accuracy. In design the unit is a conventional multifinger wiping contact switch. Its features are credited to a special insulating material that eliminates tracking or leaks between contacts through grains of contact material that adhere to the insulator surface.

Max sampling speed with ten switch-disks is 640 points per second at a speed of 600 rpm. The insulation resistance is 200 Meg at 500 Vdc.

CIRCLE NO. 166

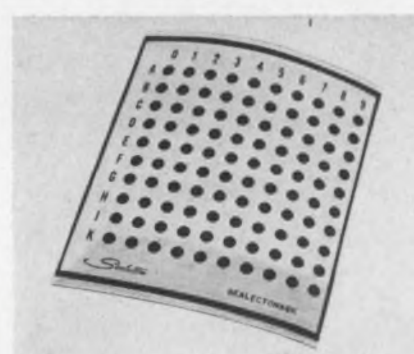


Programed relay switches 15 amps

Cornell-Dubilier Electronics, 50 Paris St., Newark, N. J. Phone: (201) 624-7500.

Switching capability is rated at 15 A, 125-250 Vac for the 1460 series programed relays. The unit mounting up to 3 form-C switches, is intended for use in sequential controls in the industrial and commercial market. Programing is provided by cam geometry. The cam is driven by a small ratchet and pawl mechanism. Optional items, such as a coil harness to accept 1/4-in. quick-connect terminals, are available.

CIRCLE NO. 167



Matrix mask guides programing

Sealectro Corp., 225 Hoyt St., Mamaroneck. N. Y. Phone: (914) 698-5600.

A 10 x 10 program mask is offered as a means of insuring error-free programing of complex functions on matrix program boards. Called Sealectomask, the template is made of Mylar film 0.005-in. thick. In use, it is prepunched to allow a shorting-pin only at the correct points. Masks for larger programing boards or multiple boards are also available.

CIRCLE NO. 168

ON READER-SERVICE CARD CIRCLE 65 ➤

Open These Gifts First

For those dreaming of computers for Christmas, or instrumentation using digital techniques, we have two free gifts for you — that really should be opened first.

Just published is a 540-page Handbook of Small Computers, which begins with a primer (or, what everyone should know about small computers), and goes on to describe, in detail, three of the most exciting small computers in the industry. The PDP-8/S, the PDP-8, and the LINC-8 are general purpose, on-line, real time, Fortran-speaking machines that are friendly, approachable, creatively adaptable . . . Prices begin at $10,000 for a complete computer.

The 330-page Digital Logic Handbook describes four series of Flip Chip™ modules, which are not only ideal for interfacing with the computers, but from which most digital instrumentation can be made. The handbook describes the logic in detail, as well as applications.

Write for your presents.

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COMPUTERS · MODULES

DIGITAL EQUIPMENT CORPORATION, Maynard, Massachusetts 01754. Telephone: (617) 897-8821 • Cambridge, Mass. • New Haven • Washington, D. C. • Parsippany, N. J. • Rochester, N. Y. • Philadelphia • Huntsville • Pittsburgh • Chicago • Denver • Ann Arbor • Houston • Los Angeles • Palo Alto • Seattle • Carleton Place and Toronto, Ont. • Reading, England • Paris, France • Munich and Cologne, Germany • Sydney and West Perth, Australia • Modules distributed also through Allied Radio

25 and 50 Q-factors for varactor line

Eastron Corp., 25 Locust St., Haverhill, Mass. Phone: (617) 373-3824. P&A: $3.50-$25.00; stock-30 days.

With capacities of 1 to 5 pF at 4 Vdc, the MC200-205 and MC300-305 voltage-variable capacitors have a minimum Q-factor of 25 and 50 respectively. Minimum inverse current for both series is 0.1 μ amp at 50 V and PIV rating is 60 V. The components are available in 5, 10 and 20% tolerances. They are glass encapsulated in an axial-lead package 55% smaller than the DO-7.

CIRCLE NO. 169

Trio-pentode tube for TV application

General Electric, 2100 Gardiner Lane, Louisville, Kentucky. Phone: (502) 459-4323.

Designed for use in color television receivers, the Compactron 6AG9 contains a triode and a high-transconductance frame-grid pentode. The pentode is intended for video output use and the triode for such applications as agc, sync separation or video amplification. Pentode performance is 30,000 μmhos at 28-mA plate current and dissipation of 10 watts at the plate, 1.5 watts at the screen. The amplification factor of the triode is 39 with a transconductance of 4600 μmhos and a plate current of 6.2 mA.

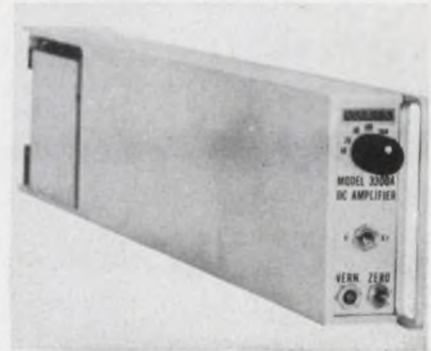
CIRCLE NO. 211

Crystal oscillator instantly "on"

MF Electronics Corp., 118 E. 25 St., New York. Phone: (212) 674-5360.

"On-off" control of the 403A gated crystal oscillator is accomplished by grounding a contact, avoiding the stabilizing time required when power-control is used. The 403A is modularly constructed and is reparable in the field. It uses 28 Vdc and generates 2 V rms into 600 Ω at fixed frequencies from 3.5 Hz to 80 kHz with a tolerance of ±0.01%, 0 to 60°C.

CIRCLE NO. 212



Differential amplifier accepts microvolt input

California Instruments Corp., 3511 Midway Dr., San Diego, Calif. Phone: (714) 224-3241. P&A: $385-$545; 30 days.

With gains from 0.5 to 2500, the five models of the 3300A differential amplifier series accept microvolt level signals from dc to 50 kHz. The compact packaging allows 12 of the 3300A series units to fit into a single 19-in. rack adapter only 3-1/2-in. high. Linearity is +0.01% of full scale and accuracy is +0.1% at fixed-gain points. The basic unit has a single fixed-gain setup between 10 and 2500, and the four other models have seven fixed-gain points plus vernier.

CIRCLE NO. 213

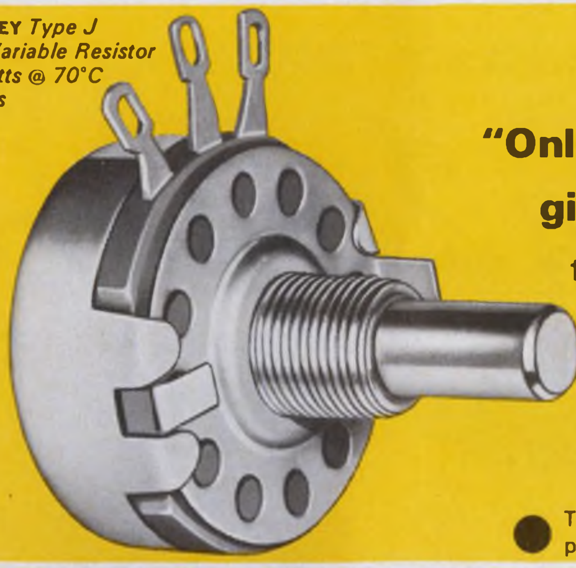
Coded output switches stress flexibility

Co-Ord Switch, 102-48 43 Ave., Corona, N. Y. Phone: (212) 899-5588. Price: from $6.95/decade.

A wide variety of binary codes are offered by the 63030 computer coded-output switches. Insertion of a single pin provides a 3-, 4-, 5- or 6-bit word output. Decades can be provided in 1248, 1247, 1125, 1224 and other codes specified. The switches are offered as an option to standard thumbwheels.

CIRCLE NO. 214

ALLEN-BRADLEY *Type J Hot Molded Variable Resistor rated 2.25 watts @ 70°C shown 2 times actual size.*

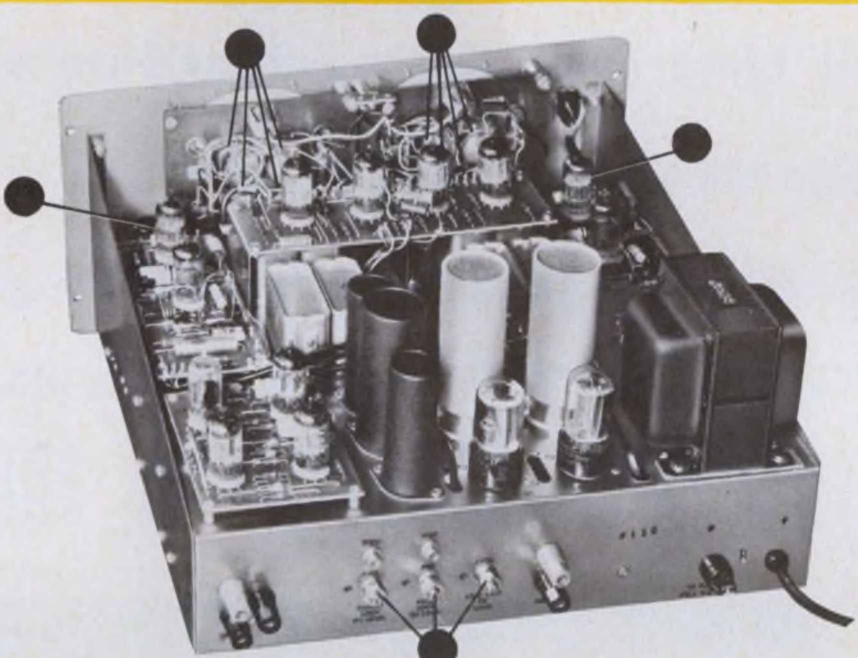


"Only Allen-Bradley Type J pots give us the smooth control

to maintain the high calibration accuracy of our instruments"

Krohn-Hite Corporation

● This quickly locates the positions of the Type J potentiometers in the illustration below.



THIS KROHN-HITE VARIABLE FILTER provides low-pass, high-pass, band-pass, and band-reject operation with high and low cutoff frequencies independently adjustable from 0.02 cps to 20 kc.

IN THE MODEL 335, continuous tuning of the high and low cutoff frequencies is accomplished by simultaneously varying four potentiometers with a single knob. Only A-B Type J controls have been found to provide the smooth control and precise tracking without discontinuities to achieve the required calibration accuracy.

■ Krohn-Hite engineers have found that only Allen-Bradley Type J potentiometers provide the smooth control, low noise, long term stability, and low temperature coefficient they require for their precision instruments such as the variable electronic filter.

The Type J control has the resistor, terminals, faceplate mounting bushing, and insulating material hot molded into a solid integral unit. The solid resistance track assures smooth, quiet control that is free from the undesirable discrete steps of wire-wound units. On accelerated tests, Type J exceeds 100,000 complete operations with less than 10% resistance change.

Insure the performance of your equipment by insisting on Allen-Bradley Type J hot molded potentiometers. Besides, when you use Allen-Bradley fixed and variable hot molded composition resistors you provide your apparatus with the label of "quality." For more complete specifications, please write for Publication 6024: Allen-Bradley Co., 1344 S. Second St., Milwaukee, Wis. 53204. In Canada: Allen-Bradley Canada Ltd. Export Office: 630 Third Ave., New York, N.Y., U.S.A. 10017.

ADDITIONAL ALLEN-BRADLEY HOT MOLDED VARIABLE RESISTORS

TYPE G CONTROLS are only ½" in diameter. Quiet, stepless operation. Rated ½ watt at 70°C. Values to 5 megohms. Type L are similar in construction but rated ½ watt at 100°C.

TYPE F CONTROLS are for mounting directly on printed wiring boards by means of their terminals. Rated ¼ watt at 70°C. Values to 5 megohms. Type O are similar but rated 0.4 watt at 70°C.

TYPE R ADJUSTABLE FIXED RESISTORS are built to withstand environmental extremes. Only 1¼" in length. Have stepless adjustment. Watertight and can be encapsulated. Rated ¼ watt at 70°C. Values to 2.5 megohms. Type N for less severe environments are rated ⅓ watt at 50°C.

166-3AB

ALLEN-BRADLEY

QUALITY ELECTRONIC COMPONENTS

ON READER-SERVICE CARD CIRCLE 67

FIRST PRIZE:

win 2 round-trip New York

- **All Electronic Design subscribers are**
- **Over 100 other valuable prizes!**
- **Guess the top ten ads in Electronic Design's**
- **"ELECTRONICS IN THE WORLD OF TOMORROW"**

Electronic Design's 1967

2ND PRIZE

HOFFMAN COLOR TV CONSOLE

Hoffman 23" console, featuring 26,000 volts of picture tube power . . . 4" x 6" front-firing speaker . . . easy vision camera control for sharp color movies and positive, black and white picture shading . . . InstaVision on-off control . . . 32" x 29" x 19⅛" cabinet. (Retail value: $600.00.)

3RD TO 8TH PRIZES

BULOVA ACCUTRON® ELECTRONIC TIMEPIECES

The "Spaceview" is an ideal timepiece for electronics engineers. Its clear-view dial reveals transistorized electronic circuit and tuning fork assembly. The tuning fork, advertising symbol and unique frequency standard of Accutron® timepieces, is the reason Bulova guarantees an in-use, on-the-wrist accuracy of within 60 seconds a month. (Retail value: $150.00.)

PLUS 100 ADDITIONAL PRIZES

MICROELECTRONIC DESIGN

This clothbound, 8½ x 11, 320-page, 1966 edition will be given free to 100 winners. "Microelectronic Design" offers a thorough overview of the field in six sections—has almost 90 outstanding articles compiled from the pages of *Electronic Design*. Edited by Howard Bierman. (Retail value: $11.50.)

SEPARATE CONTEST FOR MANUFACTURERS AND ADVERTISING AGENCIES

Not forgotten in the *"Top Ten"* contest, advertisers and their agencies may also enter. In addition to prizes of a **flight to Paris, color TV, and electronic timepiece,** the top 10 ads, and the winning advertiser's ad (if run January 4, 1967) will be re-run in the April 1st issue. Watch for the special *"Top Ten"* contest rules and entry blanks appearing January 4, 1967

tickets between and PARIS
VIA AIR FRANCE

eligible!

January 4 issue

"Top Ten" contest

HERE'S ALL YOU HAVE TO DO TO ENTER:

Rate the ads appearing in the January 4, 1967 issue of *Electronic Design*. Select the *"Top Ten"* . . . the ads that, in your opinion, will be best remembered by readers. Your choices will be measured against the 10 ads ranking highest in the "Recall-Seen" category of Reader Recall—Electronic Design's scientific method of measuring readership. In making your predictions, be sure to consider your 54,000 fellow engineers' interest in the subject matter of the ads, their effectiveness, impact, and attention-getting values.

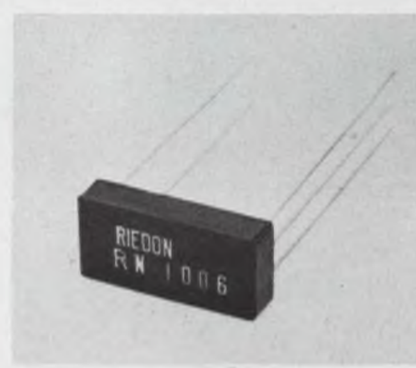
Entry blanks and complete contest rules will appear in the January 4th issue. Don't miss this opportunity to win one of the many valuable prizes shown at left. The first prize winner will receive round-trip tickets for two, between New York and Paris via Air France!

Hermetically sealed subminiature connectors

Deutsch Co., Electronic Components Div., Municipal Airport, Banning, Calif. Phone: (714) 849-6701.

Said to be ideally suited for use in transducers, transmitters, radars and submersible units, the MD plug and receptacle connectors are hermetically sealed. The mated pair is 1-in. long with a 5/8-in. diameter mounting flange. They are made of corrosion resistant alloys in a variety of mounting styles . . . solder, square flange, weld or jam nut.

CIRCLE NO. 215

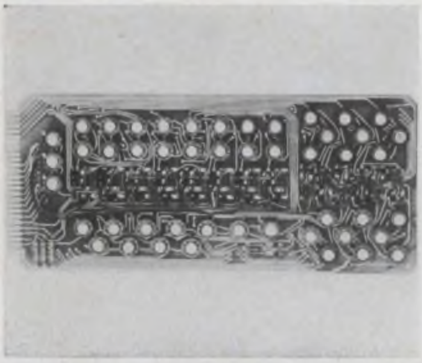


Voltage references accurate to ±0.01%

Riedon Avionics, Inc., 7932 Haskell Ave., Van Nuys, Calif. Phone: (213) 873-3464. P&A: $100; 4 weeks.

A voltage reference network that can be produced to your specifications features accuracies as close as ±0.01%. Stability rating for the design is better than ±0.002% under load for 1000 hours. Regulation can be held to 0.03% with an input voltage change of 0.5%. The reference networks can be produced to your exact specifications and are also available in manufacturer's standard models.

CIRCLE NO. 216



Convert digits to phase information

Servo Corp. of America, 111 New S. Rd., Hicksville, N. Y. Phone: (516) 938-9700.

The solid-state digital-to-synchro converter, model 201 is offered as a stock item in production quantities. The converter is designed to accept parallel 11-bit words representing shaft angles and convert them to 400-Hz, 3-wire or 4-wire resolver information. The system's 4-5/8-in. cards are also available individually. The 201 consists of three of these cards, and logic.

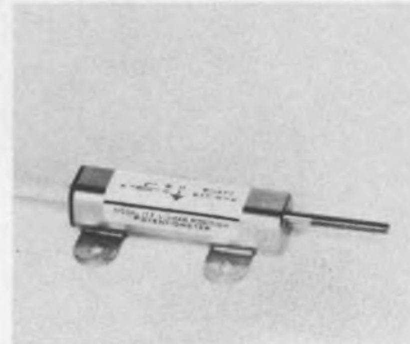
CIRCLE NO. 217

Ceramic trimmer occupies 0.007-in.^{3}

Erie Technological Products, Inc., 6444 West 12 St., Erie, Pa. Phone: (814) 456-8592.

A capacitance range of 5 to 25 pF is packed into the 0.007-in.^{3} model 518 ceramic trimmer. The component is rated at 100 Vdc to 85°C and 50 Vdc to 125°C. The unit's range and capacity are said to be the result of a construction process in which ceramic film dielectrics are fired into solid structures of one or more layers. Dielectric strength is rated 200 Vdc.

CIRCLE NO. 218



Infinite resolution from a linear transducer

Bourns Inc., 1200 Columbia Ave., Riverside, Calif. Phone: (714) 684-1700.

Chief feature of the Model 177 linear position transducer is the use of the "Infinitron" resistance element, providing continuous resolution. This element is also said to provide a longer life expectancy than comparable wirewound elements. Ranges are 0.5 and 1.0 inch with resistances of 250 to 15 kΩ and a tolerance of ±5%.

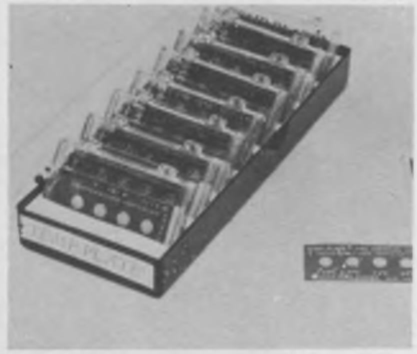
CIRCLE NO. 219

Synchro-input servo housed in 23 frame

Ocean Technology Inc., 777 Front St., Burbank, Calif. Phone: (213) 849-6477. P&A: $750; stock to 60 days.

A miniaturized synchro-input servo mechanism is housed in a size 23 frame. The unit includes its own error or follow-up synchro, power supply, servoamplifier and motor. Designated OTR-23, it provides zero-backlash operation with an accuracy of 0.25°. It is directly interchangeable mechanically and electrically with any 23TR synchro and accepts either 60- or 400-Hz inputs.

CIRCLE NO. 220



Decals record peak ambient temperatures

William Wahl Corp., 1001 Colorado Ave., Santa Monica, Calif. Phone: (213) 393-6419.

"Temp-Plate" temperature recording decals provide an irreversible reading when specified peak temperatures are reached. The range of temperatures available is from 100 through 1100°F, normally in 10° gradients with a ±1% accuracy factor. Kits have been selected for such industries as electronics, aircraft and aerospace. Complete lot control and traceability is provided with each indicator.

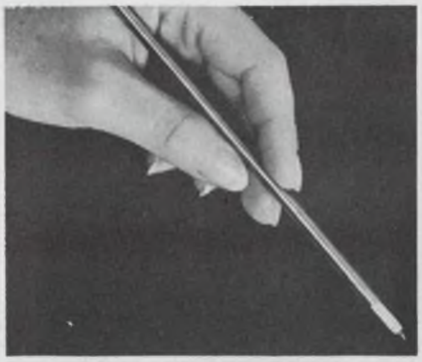
CIRCLE NO. 221

Miniature reeds switch up to 750 mA

C. P. Clare & Co., 3101 Pratt Blvd., Chicago. Phone: (312) 262-7700.

In PC board use, "MicroClareed" relays Type MRME and MRMC offer switching capability up to 750 mA. The MRME molded epoxy module and the MRMC open-coil module provide for 1 to 5 Form A contacts and occupy a max of 0.406 in.^{3} of board space. Voltage rating is 200 Vdc, 110 Vac max and load is 10 VA. Coil voltages range from 6 to 48 Vdc.

CIRCLE NO. 222

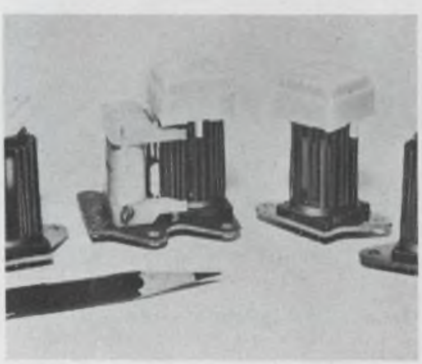


Probe-type transducer repeatable at ±1%

Thermal Systems, Inc., 15100 South Broadway, Gardena, Calif. Phone: (213) 321-4350.

Precision platinum temperature transducers are offered for a range of 100 to 400°C with a repeatability factor of ±1%. Probes consist of reference grade platinum with a resistance factor of 100 Ω at 0°C wound strain-free on a mandrel. Long-term reliability is assured by a thermal shock test. Applications are seen in commercial process control equipment.

CIRCLE NO. 223



Pushbuttons, toggles meet esthetic specs

American Zettler, Inc., 697 Randolph Avenue, Costa Mesa, Calif. Phone: (714) 540-4190. Price: $0.75 to $2.70.

Designed with esthetics in mind, the Series T-500 pushbutton and toggle switches are also panel space savers. Overall depth behind the panel is 1.5 in. The switches can be mounted directly with other electronics so that the front panel serves only as a cover plate. Square and round pushbuttons of the line can be illuminated.

CIRCLE NO. 224

SPEED SEQUENTIAL

Push a Button..

CONDENSED SPECIFICATIONS

MODEL 155A OSCILLOSCOPE

Vertical Deflection System

Deflection Factor (Sensitivity): 5 mv/cm to 20 v/cm.

Bandwidth: DC coupled: DC to greater than 25 MHz. AC coupled: 2 Hz to greater than 25 MHz.

Position: Base line can be offset $\pm$ 25 cm from center screen of CRT in calibrated steps.

Signal Delay: Signal is delayed so that leading edge of fast rise signals is visible at start of sweep.

Input Impedance: 1 megohm shunted by approximately 50 pf.

Horizontal Deflection System

Internal Sweep: From 0.1 μs/cm to 50 ms/cm.

Magnification: X 5 expansion available on all ranges.

Slow Sweeps: $\div$ 10 slows sweep to 0.1 sec/cm, 0.2 sec/cm, or 0.5 sec/cm.

Triggering:

Automatic: Internal, external, or from line.

Trigger Slope: Positive or negative.

Amplitude Selection: Internal, or external.

Trigger Point and Slope: Internally from any point on the displayed wave form; externally from any point between $\pm$ 5 volts, positive or negative slope.

Single Sweep: Front panel switch selects single sweep operation.

Remote Programming

Programming is accomplished by contact closures to an isolated common line. Programmable functions are listed below.

Vertical: Deflection factor (sensitivity). Input coupling. Vertical positioning.

Horizontal: Sweep time. Trigger source. Trigger slope.

Price: $2450.00.

MODEL 1550A PROGRAMMER

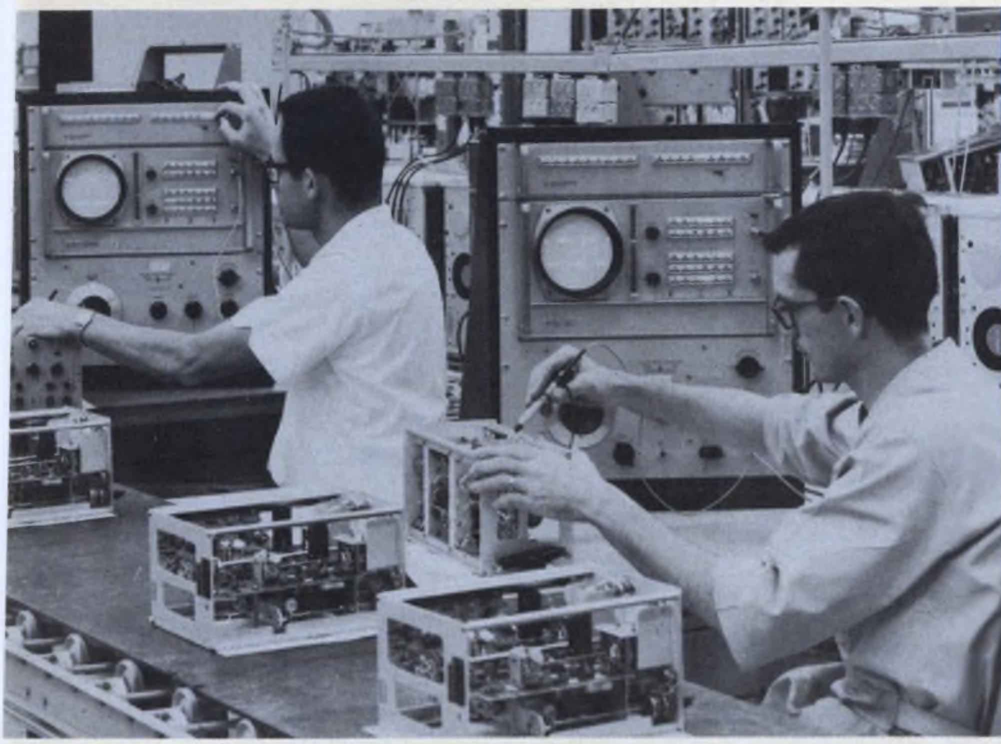
Up to 18 programs can be preset in the 1550A Programmer. Plug-in diodes provide the means for programming vertical sensitivity, vertical positioning, vertical input coupling, sweep time, trigger source, and trigger slope in the 155A Programmable Oscilloscope.

Price: $600.00.

WAVEFORM TESTS

Read a Trace!

NEW PUSH-BUTTON, PROGRAMMABLE OSCILLOSCOPE



- Push-Button Speed
- All Major Functions Digitally Programmed
- No DC Drift
- ± 25 cm Calibrated Positioning
- High Sensitivity 5 mv/cm
- Wide Bandwidth 25 MHz

Sequential testing is now a one-two procedure with the new hp Model 155A/1550A Push-Button, Programmable Oscilloscope! All you do is select a test point, then – *push a button . . . and read a trace.*

This new automated hp oscilloscope is the first scope specifically designed for production line and automatic systems applications. It will reduce test time per unit, simplify test procedures, minimize operator errors, shorten training time – and can even reduce the number of required test stations! Check-out routines in automatic systems are speeded by eliminating all manual adjustments.

The 155A oscilloscope embodies all the features of a conventional laboratory instrument, with push-button convenience. Most frequently used controls are located on the front panel. All other controls are located behind the swing-down access door.

You can insert up to 18 test programs in each 1550A digital programmer, or cascade programmers for additional capability. Each test program can control any or all major scope functions – including vertical positioning, sensitivity, input coupling, sweep time, trigger source, and trigger slope – with the press of a button! Each programmed function can be manually over-ridden at any time. Back-lighted indicators show program, sweep, sensitivity, and vertical position for error-free readout.

Only a few minutes are required to insert diode pins for setting up programs in the all-digital programmer. Diode-controlled, digital programming makes the 155A/1550A fully compatible with any contact-closure-to-ground programmer for high speed, automatic check-out systems.

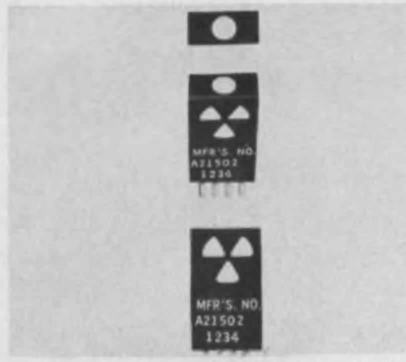
Measurements are repeatable, because the unique hp DC stabilizer circuitry eliminates DC drift. The trace stays where it is positioned for measurement confidence, regardless of sensitivity or sweep. Calibrated positioning over ± 25 cm dynamic range can eliminate need for voltmeters. Typical DC measurement accuracy is ± 2% of reading.

To find out what this *new measure of scope performance* means to you in speeding your sequential testing, call your nearest hp sales office for a demonstration of the new hp Model 155A/1550A Push-Button Programmable Oscilloscope. Or, write Hewlett-Packard, Palo Alto, California 94304, Tel. (415) 326-7000; Europe: 54 Route des Acacias, Geneva. Price: hp Model 155A Oscilloscope, $2450.00; hp Model 1550A Programmer, $600.00, f.o.b. factory.

HEWLETT hp PACKARD

An extra measure of quality

ON READER-SERVICE CARD CIRCLE 75

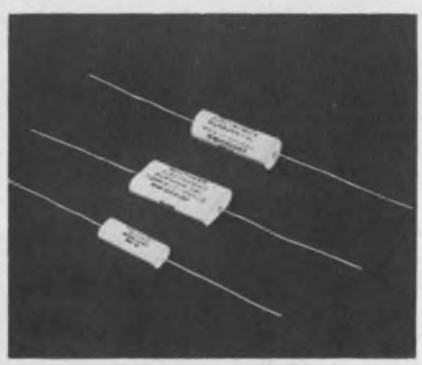


"Bite" indicator monitor in avionics

A. W. Haydon Co., 232 N. Elm St., Waterbury, Conn. Phone: (203) 756-4481.

To meet DOD requirements for fault-indication in avionics equipment, a line of microminiature units is now available. Called Bite indicators for Built In Test Equipment, the units indicate a fault visually through a window on the side and front of the 0.7 x 0.2 x 0.4-in. module. They operate over a range of 17 to 29 Vdc and are activated by pulses down to 15 msec.

CIRCLE NO. 225

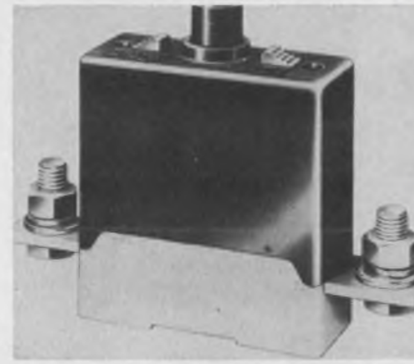


Polycarbonate caps operate to 125°C

Southern Electronics Corp., 150 W. Cypress Ave., Burbank, Calif. Phone: (213) 849-3193.

Metallized polycarbonate capacitors of the ML line are specified for operation up to 125°C. The components are available in 200, 400 and 500-volt ranges with values from 0.001 mfd. Retrace stability is less than 0.05% and insulation resistance is beyond 100,000 Meg at 25°C. The units are oval in shape for high-density applications. Hermetically sealed tubular versions are optional.

CIRCLE NO. 226



Circuit breaker has "off-on" switch

ETA Products of America, 6284 N. Cicero Ave., Chicago. Phone: (312) 545-1553.

An off-on switch mechanism on the 44-7-S-H-N breaker prevents reset during overload conditions. The breaker is available in standard current ratings from 125 to 400 A at 28 Vdc. The breaker button can only be operated in conjunction with the slider latches to prevent accidental operation. Max interrupting capacity is 10,000 A at 28 Vdc.

CIRCLE NO. 227

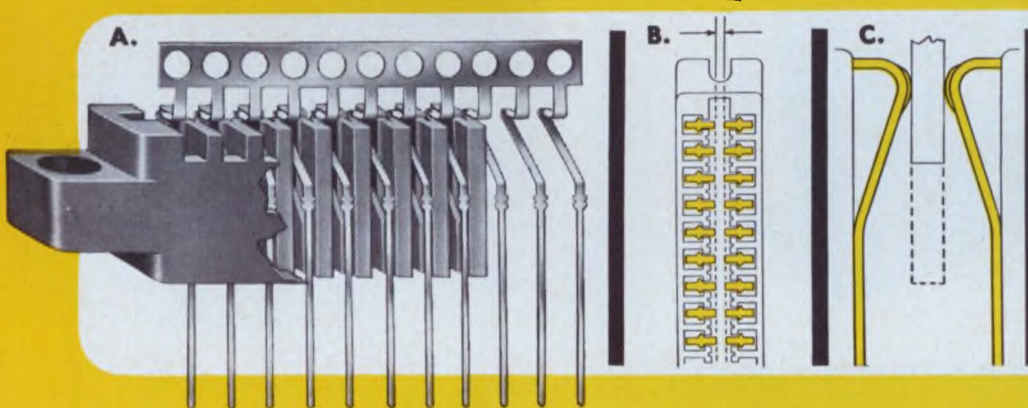
Shielded transformers transfer below 0.1 μF

United Transformer Co., 150 Varick St., New York. Phone: (212) 255-3500.

For critical circuitry, isolation close to that of battery power is claimed for the HIT 450 ultra-shielded power-line isolation transformers. The rated capacity coupling between primary and secondary windings is less than 0.1 μF which can be reduced even farther by the circuit design. For 400-Hz operation, MIL power rating is 80 W and specifications of MIL-T-27B are guaranteed.

CIRCLE NO. 228

Cinch gives you the tail stability you need for programmed wire wrapping— in a miniature p.c. connector



A. Tail stability is provided by the comb contact construction which permits force fit through the insulator.

B. Gap uniformity is achieved through preloading contact against insulator stop.

C. Contact pressure is independent of P-C board insertion depth because of contact profile.

Cinch has combined cantilevered contact reliability with .025″ square tail wrapping speed. This new Cinch high contact density printed circuit board connector can be wired at a rate of up to 750 net wires per hour with a Gardner-Denver automatic wire wrap machine. This is more than 15% faster than for .045″ square tail connectors.

This new connector uses a comb contact assembly which provides the gap uniformity of preloaded cantilever construction and contact pressure which is independent of printed circuit board insertion depth. Contacts are on .125″ centers. Construction combines minimum insertion force with maximum contact pressure.

The connector is especially suited for programmed automatic wire wrap applications and is particularly well designed for use with the latest packaging techniques, particularly the dense packaging currently being developed for electronic data processing equipment. For cost reduction in volume applications the precision contacts can be *selectively gold plated*. This Cinch developed technique substantially reduces the amount of gold required, resulting in lower connector costs.

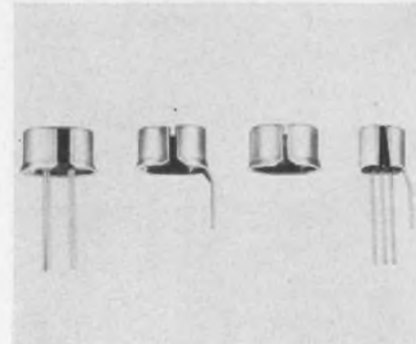
These precision tooled comb contacts are precisely and automatically preloaded with insertion of the comb into the insulator. The true tip location in the required position for automatic wrapping equipment is assured by the comb assembly technique. This technique employs a force fit to the insulator, assuring rigid, exact positioning. Cinch also manufactures .045″ square tail rectangular terminal and other wire wrap terminated printed circuit board connectors suitable for use with the automatic wire wrap equipment manufactured by Gardner-Denver.

For additional information, write to Cinch Manufacturing Company, 1026 S. Homan Avenue, Chicago, Illinois 60624.

CM6619

CINCH

DIVISION OF UNITED-CARR

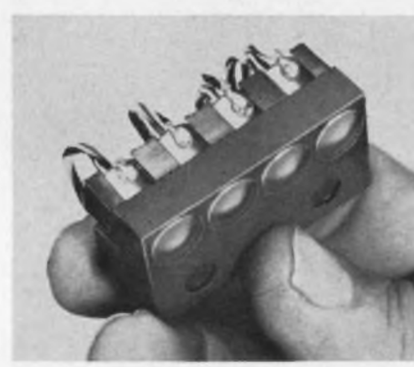


Brass clips for plastic transistors

Wakefield Engineering, Inc., Wakefield, Mass. Phone: (617) 936-3069. P&A: $7.25 to $8.50/M; stock.

For use as an electrostatic shield and/or thermal retainer, three types of brass clips mate plastic transistors. Type 256-ST shield mounts a single device. Type 256-DT is also a shield but mounts two devices. Type 256-D is a thermal retainer without a shield and holds two transistors at equal temperature. The clips are formed of 1/2 hard brass.

CIRCLE NO. 229



Proximity switch uses Hg-wetted contacts

General Equipment & Mfg. Co., 3300 Fern Valley Rd., Louisville, Ky. Phone: (502) 969-2386.

Mercury-wetted contacts are credited with providing reliable, bounce-free operation in a miniature proximity switch by General Equipment and Mfg. Unit-life is said to run into billions of cycles and operation at 3600 cycles per minute is possible. In a typical application, the switch is used in 64 circuits on a 14-in. magnet, and each switch is operated only by its individual operator.

CIRCLE NO. 230

Fast, convenient direct reading measurements of impedance and phase angle 500 kHz to 108 MHz...

THE 4815A RF VECTOR IMPEDANCE METER

This new Vector Impedance Meter is a versatile instrument that provides fast, direct reading measurements of impedance and phase angle over the frequency range from 500 kHz to 108 MHz. It is continuous tuning over this frequency range, and does not require balancing or data interpretation. Thus, it is an extremely useful tool for the evaluation of the complex impedance of both active circuits and components. The convenience of probe measurement, ease of operation, and direct reading features make the instrument equally useful for laboratory, receiving inspection or production line measurements.

The 4815A is a convenient and powerful measuring tool for any application involving measurements over a band of frequencies or in-circuit measurements. It may be used to determine the self-resonance point of capacitors, the series and parallel resonance points of crystals, or the characteristics of high frequency transformers and transducers. Price: $2650 f.o.b. factory. For complete specifications, contact your local Hewlett-Packard field engineer or write Hewlett-Packard, Rockaway Division, Green Pond Road, Rockaway, N. J. 07866; Europe: 54 Route des Acacias, Geneva.

Advantages:

Fast, continuous tuning from 500 kHz to 108 MHz

Provides data directly in impedance and phase angle, 1 ohm to 100K ohms 0 to 360°

Convenient probe for in-circuit measurements

Analog outputs permit permanent data recording

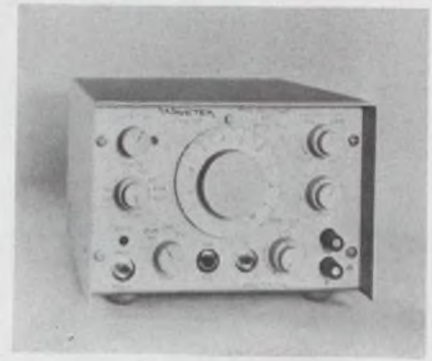
Self calibration check provides measurement confidence

Low-level test signal minimizes circuit disturbance

HEWLETT hp PACKARD

An extra measure of quality

ON READER-SERVICE CARD CIRCLE 79



Portable generators operate in 3 modes

Wavetek, 8159 Engineer Rd., San Diego, Calif. Phone: (714) 279-2200. Price: $745 to $945.

Triggered or gated operation as well as phase-lock capability are offered in the Model 115 function generator. In the trigger mode, a manual or external voltage generates one cycle. In the gated mode, a discrete number of cycles are keyed by a ±5-V gate. The unit will lock to any input within 10:1 of dial frequency and phase-lock to the fundamental of the dial frequency within specified accuracy.

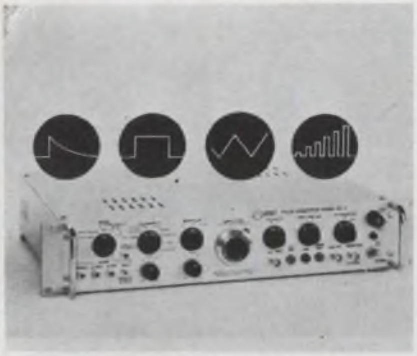
CIRCLE NO. 231

Tracing transmitter for fault location

Hipotronics, Inc., Route 22, Brewster, N. Y., Phone: (914) 279-8484.

Location of faults, cable and phase identification, and continuity testing is accomplished by the Model 8030-30TC low-voltage tracing current transmitter. The instrument delivers 30 Vdc at 30 A pulse-coded into a three-phase cable, in a system called directional impulse tracing. It is designed to be hand carried and has continuously adjustable output control.

CIRCLE NO. 232



Sliding pulser gives ramp-effect trains

Berkeley Nucleonics, Berkeley, Calif. Phone: (415) 848-1457. P&A: $1460; 30 days.

The GL-3 provides a pulse train of linearly increasing amplitude for applications such as testing differential linearity of amplifiers and pulse-height analyzers. The instrument also generates precision amplitude pulses for conventional testing. In the sliding pulse mode, linearity is rated better than ±0.25% with a pulse rep-rate of 1 Hz to 1 MHz. Stable pulse mode linearity is ±0.1%.

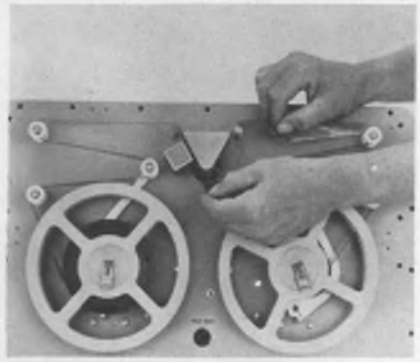
CIRCLE NO. 233

Analyzer evaluates magnetic materials

Adar Associates, Inc., 73 Union St., Somerville, Mass. Phone: (617) 623-3131.

Evaluation of magnetic materials is the function of a multi-channel current-pulse-train generator. The solid-state instrument features programable operation, variable pulse current/voltage calibration and operational speed. Called the P1-D_1 core analyzer, the generator is packaged as a plug-in to fit Tektronix scopes.

CIRCLE NO. 234

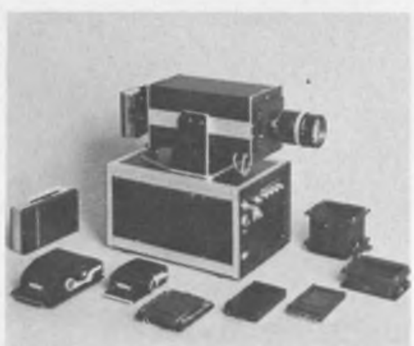


Photoelectric reader lives in a suitcase

Electronic Engineering Co., 1601 E. Chestnut Ave., Santa Ana, Calif. Phone: (714) 547-5501.

For airborne, mobile or suitcase use, the 3002 photoelectric punched tape reader is completely ruggedized. The unit's direct coupled stepping motor drives the tape in either direction at rates up to 200 ch/s. The tape advances one character for each read-command, stopping on a character at all speeds. Design meets environmental specs of MIL-T-21200, Class 2.

CIRCLE NO. 235



Modular camera nets flexibility

Electro-Optical Instruments, 441 Whisman Rd., Mountain View, Calif. Phone: (415) 968-6220. Price: from $4950.

For quantitative nanosecond photography, the modular "building-block" image converter camera X500 records at speeds from 5 to 1000 ns. Pictures recorded are up to 3-1/2-in. in diameter with 760 resolved line pairs across the field. X500 system components are interchangeable, including three heads and controls for single- or multi-frame configurations.

CIRCLE NO. 236

IC card tester patch programed

Wyle Laboratories, 133 Center St., El Segundo, Calif. Phone: (213) 322-1763.

Rapid go no-go testing of IC cards is provided by the Model 1569. The instrument is programed by a front panel patch-cord board and for high-volume repetitive testing, prepatched panels can be provided. A check of both logic function and voltage level is provided by the instrument and a counter indicator allows you to determine the exact malfunction.

CIRCLE NO. 237

Time-code generator uses integrated logic

Parabam, Inc., 12822 Yukon Ave., Hawthorne, Calif. Phone: (213) 679-3393. Price: $2,000.

The Series M digital clock time code generator features IC logic. It provides times information in BCD form for time transmission, range timing, time display and data systems. Time base is developed from the power line frequency or from optional internal oscillators. A variety of BCD output formats are available. Options for special applications such as controlling output at an external clock rate, remote start-stop and special pulse outputs are also offered.

CIRCLE NO. 238

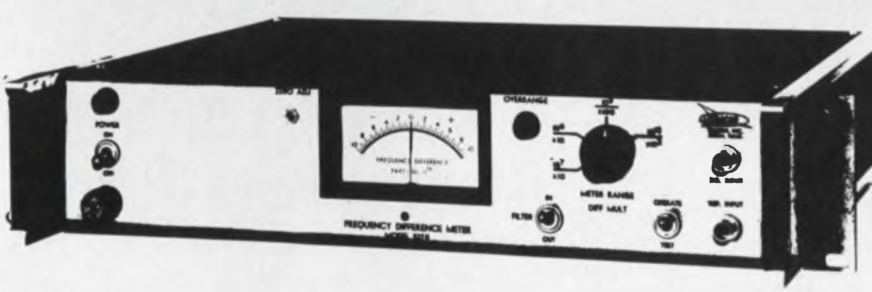
Do you have to "ride herd" on drifting oscillators?

. . . and need to check frequency periodically, monitor regularly, or adjust to a standard?

Then the TRACOR direct-reading Model 527B Frequency Difference Meter is just what you need. It determines instantly—with an accuracy of 10^{-10} — the fractional frequency difference between two stable oscillators.

It includes most of the features of its "big brother", the 527A, but costs much less. You read directly on a zero-center front-panel meter fractional frequency difference in parts per 10^7, 10^8, 10^9 or 10^{10}. The meter movement continuously follows your oscillator adjustment — provides instantaneous reading of oscillator correction.

You may change the input frequencies without switching ...... frequencies of the two input signals need not be the same. The 527B accepts inputs of 100 kHz, 1.0 MHz, 2.5 MHz and 5.0 MHz; it is ideally suited for rating crystal oscillators. The 527B, when used with your counter, will allow you to measure differences of parts in 10^{12}.

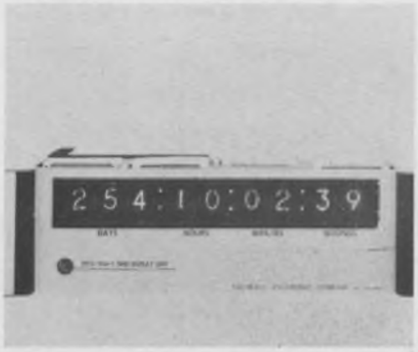


The Model 527B sells for $2,250. For more information on this advanced-technology product, please write or call: TRACOR, INC., 6500 Tracor Lane, Austin, Texas 78721 AC 512 926-2800.

Time & Frequency Instruments by TRACOR

TFA-1466

ON READER-SERVICE CARD CIRCLE 83

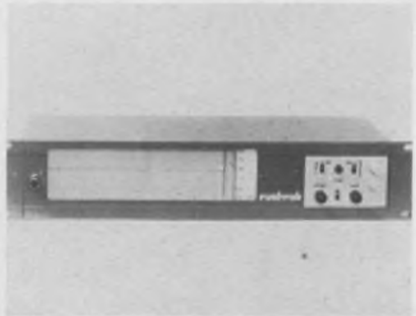


Time-display units operate remotely

Electronic Engineering Co., 1601 E. Chestnut Ave., Santa Ana, Calif. Phone: (714) 547-5501. Price: from $850.

It is possible to have time information as produced by a time-code generator visible at any location in a test facility. A series of time display units, using Nixie displays can be located at any distance up to several miles from the generator. Models are available to operate from time codes in either serial-modulated carrier form or in parallel form.

CIRCLE NO. 239



Recording systems have extended view

Rustrak Instrument Co., Inc., Municipal Airport, Manchester, N. H. Phone: (603) 623-3596.

An extended-view design of the manufacturer's recording systems allows up to 17-in. of recorded information to be examined. The systems consist of a miniature strip-chart recorder plus an amplifier or other accessories. The recorder uses an inkless dry-writing process. Chart speeds vary from 1/16 in. to 1800 feet per hour. At 1 in. per hour, 17 hours of recording is visible at a glance.

CIRCLE NO. 240

Low-cost oscillograph operates light-beam

Consolidated Electrodynamics Corp., 360 Sierra Madre Villa, Pasadena, Calif. Phone: (213) 796-9381.

Light-beam oscillography is said to be put into more modest budget ranges by the type 5-126 recording oscillograph. This is a 35-lb portable instrument that uses a high-intensity tungsten source, galvanometers and an optical system to produce up to 9 channels of data on 7-in. printout paper. Recording speeds range from 0.25 to 64 ips and range is dc to 1 KHz.

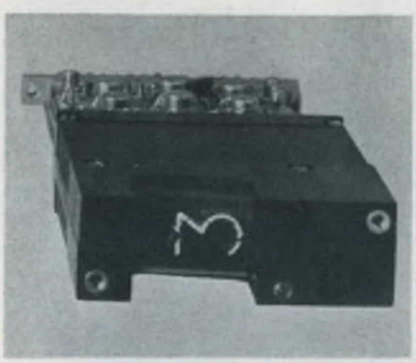
CIRCLE NO. 241

Data system has core memory unit

Information Control Corp., 138 Nevada St., El Segundo, Calif. Phone: (213) 322-6930.

A stored-program data acquisition system, the SPDAS, offers sophisticated capabilities over a wide range. The system samples as many as 100 channels, performs A/D conversions, formats data for computer compatibility and records data on magnetic tape. Key to the system is a core memory with a 4,000-word 8-bit unit capability. Conversion rates run as high as 100,000/s.

CIRCLE NO. 242

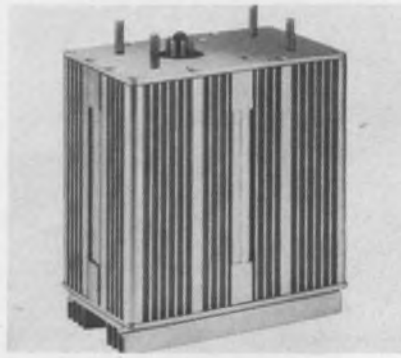


Decade counter display modular, based on ICs

Janus Control Corp., 296 Newton St., Waltham, Mass. Phone: (617) 891-4700. P&A: $96.90; stock.

The modular, 3-MHz display module Model IC-803 is based on integrated circuits. The forward-backward counter display provides in-line numerical display, base preset and 8-4-2-1 bipolar BCD outputs. It will accept forward, backward and reversing signals, either periodic or aperiodic. Modular packaging measures 3 x 1 x 6-3/4-in.

CIRCLE NO. 243



Modular supplies transistor regulated

Mid-Eastern Electronics, Inc., 15 Brown Avenue, Springfield, N. J. Phone: (201) 376-7130. P&A: $198; stock.

With neither forced air nor heat sinking, HT series transistor regulated supplies will function reliably at ambients up to 40°C. Units are available in ratings from 6 V at 4 A to 100 V at 0.75 A. Line regulation is 0.025% for a ±10-V change. Load regulation is 0.02% zero to full. Standard models have an MTBF of over 35,000 hours. MTBFs of 60,000 hours are available as a special option.

CIRCLE NO. 244

French power module designed for IC use

Sodilec Co., 4, Rue Simone Bigot, Neuilly-Plaisance (Seine-et-Oise), France.

The French-manufactured SDT 144 power module is designed specifically for use with integrated circuits. Features include constant voltage/constant current operation with automatic crossover and regulation in either mode to 0.01%. Voltage is continuously adjustable from 0 to 4 A and remote programming and regulation are also possible.

CIRCLE NO. 245

Automatic regulators stabilize to 100 mV

Superior Electric Co., Bristol, Conn. Phone: (203) 582-9561. P&A: $370-$1740; stock.

Output voltage is held within a 100-mV band regardless of line and load through the IES stabiline regulators. Time constant response for a 63% return is 30 ms. Frequency range is either 50 or 60 Hz ±10%, and efficiency is rated up to 95%. Units are offered for 115- or 230-V service with ratings up to 15 kVA.

CIRCLE NO. 246

Master outlet box monitors power line

Waber Electronics Inc., 2000 N. Second St., Philadelphia, Pa. Phone: (215) 634-3200. Price: $7.50-$9.50.

A series of master power outlet boxes continuously monitors its ac line voltage. The units, called the 230 M series, feature illuminated voltmeter readings from 0 to 150 V. Power ratings are 15 amp at 130 V continuous. Units are available with either fuse or circuit-breaker protection and with varying lengths of cord.

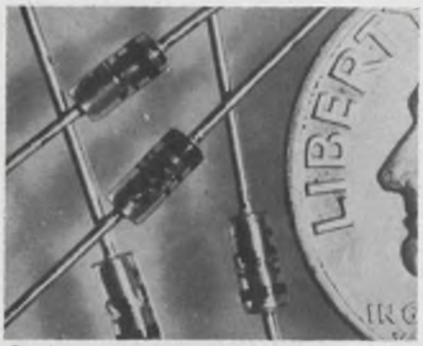
CIRCLE NO. 247

16 power modules regulated to ±0.005%

Raytheon Co., Norwalk, Conn. Phone: (203) 838-6571.

Line and load combined regulation as tight as ±0.005% is available in the 16 models of the QSB series power supplies. The dc units have ripple held to 250 μV with 1 mV peak-to-peak and a transient response of <40 μs. Stability is 0.025% for eight hours. Change in output voltage as a result of ambient temperature change is less than 0.015%/°C. The 6-28 Vdc series includes 25-200-W units.

CIRCLE NO. 248



Submin diode made "whiskerless"

Hughes Aircraft Co., Centinela Ave. & Teale St., Culver City, Calif. Phone: (213) 391-0711. P&A: from $0.37; stock.

Here's a silicon planar epitaxial diode that features whiskerless construction. Called WOW diodes (WithOut Whiskers), the subminiature devices are said to provide high mechanical strength and stability for critical circuits. They are high-conductance types designed for high-speed switching and core driver applications.

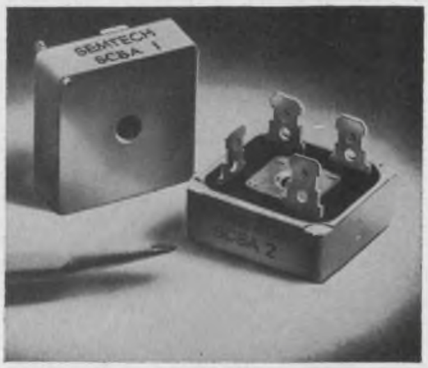
CIRCLE NO. 249

Semiconductor selection contains 300 devices

Motorola Semiconductor Products, Inc., P. O. Box 955, Phoenix. Phone: (602) 273-6900. Price: $49.50.

Circuit designers, prototypers and experimenters are offered a package containing 300 "Uniblock" semiconductors. Called HANDY-Lab, the 6-drawer package contains 11 different general-purpose npn and pnp plastic transistor types and 25 plastic dual switching diodes. Types included, 25 each, are: 2N3903, 2N3905, 2N4124, 2N4126, 2N4264, 2N4400, 2N4402, MPS706, MPS918, MPS6520 and MSD6100.

CIRCLE NO. 250

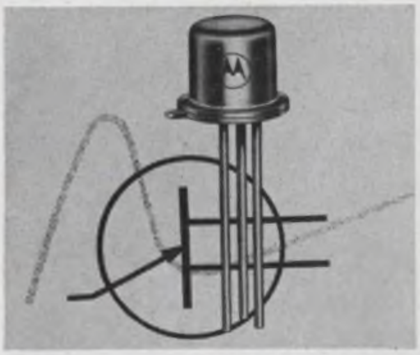


Rectifier circuit housed in aluminum

Semtech Corp., 652 Mitchell Rd., Newbury Park, Calif. Phone: (213) 628-5392.

The "Alpac" power bridge rectifier circuit is housed in an aluminum case for rugged applications. The case measures 1.125 x 1.125 x 0.406-in. and is designed for simple installation. Ratings range up to 25 A average rectified current and PIV ratings range from 50 to 600 V. The device is rated at a max thermal resistance of 1.5°C/watt.

CIRCLE NO. 251



Unijunction line for long-period oscillators

Motorola Semiconductor Products, Inc., Box 955, Phoenix, Ariz. Phone: (602) 273-4560. P&A: $0.80-$1.50; stock.

In the design of long time-delay circuits, use of the 2N4851-53 unijunction transistors is said to allow the use of comparatively small and inexpensive capacitors. Key specs on the new devices are emitter reverse and peak-point current. Both 2N4851 and 52 have an emitter reverse current rating of 0.10 μamp and a peak-point of 2.0 μamp. Intrinsic standoff ratio is 0.75 and 0.85 respectively. 2N4853 has an emitter reverse of 0.05 μamp and a peak-point of 0.4 μamp with an intrinsic standoff ratio of 0.85. Emitter saturation voltage for all three units is 2.5 V.

CIRCLE NO. 252

Current regulators act like zeners

General Semiconductors, 230 W. 5 St., Tempe, Arizona. Phone: (602) 966-7263.

A line of precision current regulators act in-circuit much like zener diodes. The two-terminal devices are suggested in such applications as squaring, timing, sweep, pulse integrators, filters, TC reference diode sources, biasing and circuit protection. Package dimensions are 0.375-in. diameter, 1-in. length with gold-plated leads. Ratings range 0.5 to 10 mA.

CIRCLE NO. 253

Wire lead line for semicon devices

Wire Forms Division of Emporium Specialties Co., Austin, Pa. Phone: (814) 647-8691.

A complete line of wire leads is now available, formed by cold-heading the ends of wires ranging between 0.008-0.060-in. These leads are offered for use as leads and terminals in resistors, transistors, diodes, etc. Wire material selection includes gold, silver, copper, tantalum, nickel and various seal materials.

CIRCLE NO. 254

Flat-cable units need no stripping

ITT Cannon Electric, 3208 Humboldt St., Los Angeles, Calif. Phone: (213) 225-1251.

Welding is performed through the insulation of the Flex-Weld flat-cable assemblies. These assemblies consist of multiple ribbons of flat copper conductors uniformly spaced and laminated between Mylar or Teflon insulation, straight or corrugated. The design is said to provide up to 50% combined weight and size reduction of comparable round-wire systems and the flat conductors dissipate more heat.

CIRCLE NO. 255

Ag-plated wire Teflon insulated

Tensolite Insulated Wire Co., W. Main St., Tarrytown, N. Y. Phone: (914) 631-2300.

Ultra-fine sizes of both mono- and multifilament Teflon insulated copper wire, silver plated, are offered for off-the-shelf delivery. The UT wires range in diameter from 0.23-0.135-in. in standard 500- and 1,000-ft spools. The Teflon insulation is chemically inert and will tolerate extremes from −90° to +200°C. The insulation is rated for 300 V.

CIRCLE NO. 256

Epoxy tape bonds honeycomb or metals

Adhesive Engineering, 1411 Industrial Rd., San Carlos, Calif. Phone: (415) 591-2686.

In both metal-to-metal and honeycomb bonding, Aerobond 3030 meets MIL-A-132 types I (class 3) and II as well as MIL-A-25463, types II and III. Aerobond 3030 is multi-purpose and can be used for both large and small-area bonding. Useful temperature is up to 550°F. Lap sheer strength ranges from 2700 psi at −67°F to 800 psi at 500°F.

CIRCLE NO. 257

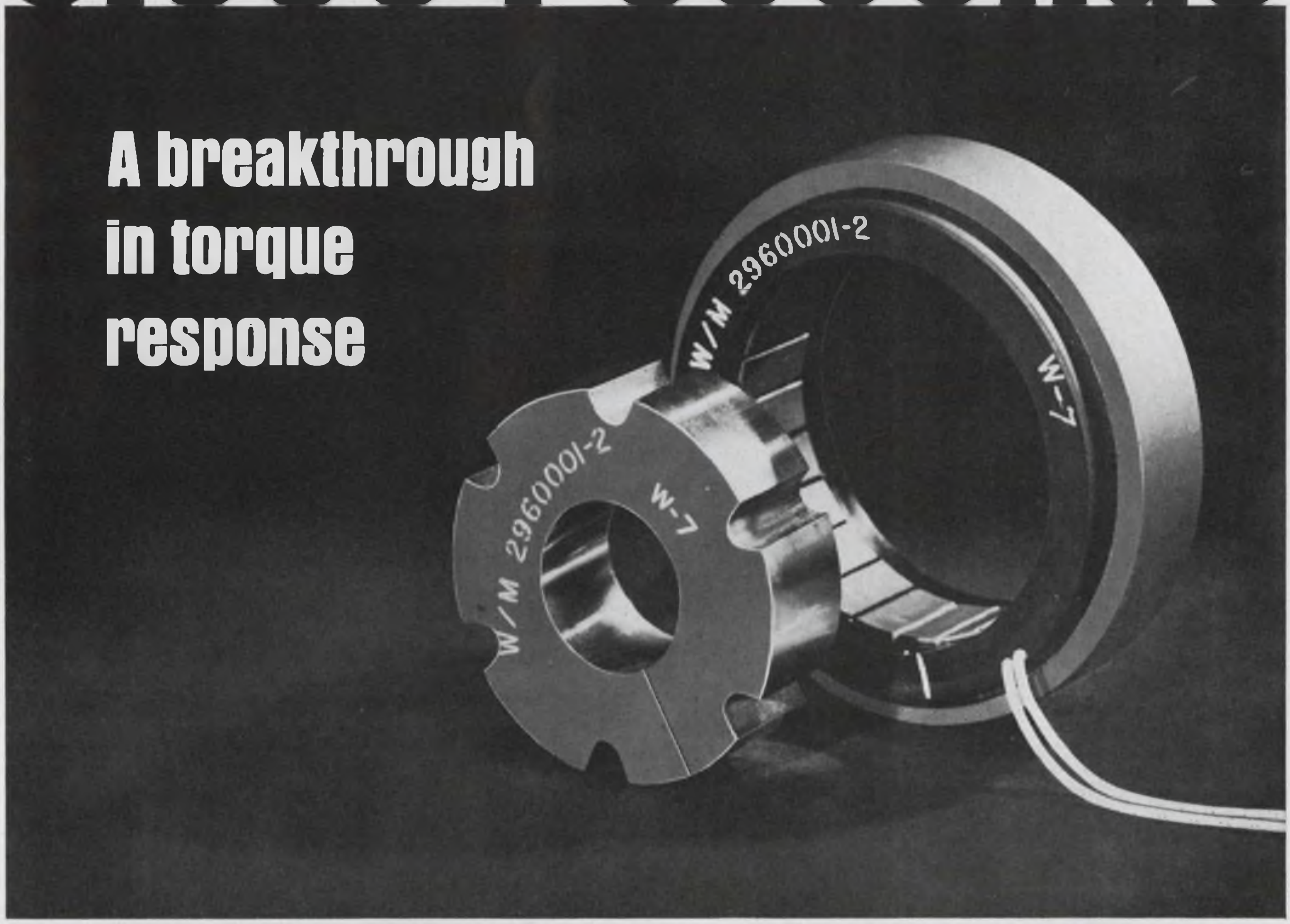
Chromium sources for sputtering

Materials Research Corp., Orangeburg, N. Y. Phone: (914) 359-4200.

For more depositions before replacement, sizes up to 1/4 x 3-1/2 x 3-1/2-in. are available in a line of high-purity chromium sputtering sources. These sources are prepared by arc casting to a purity of 99.996% nominal, including gas content. The higher purity is also said to increase production yield by eliminating impurities that affect device performance.

CIRCLE NO. 258

0.0004 seconds



Torque motors with a response of four hundred millionths of a second are now a reality. And this breakthrough is only one of several benefits offered you in a new line of torquers by Wright Division of Sperry Rand.

SIZE	O.D.	Watts at Peak Torque	Design: 2 Pole 180° Peak Torque Oz.-In.	Design: 2 Pole 180° Electrical Time Constant L/R (Secs.)	Design: 4 Pole 90° Peak Torque Oz.-In.	Design: 4 Pole 90° Electrical Time Constant L/R (Secs.)	Design: 6 Pole 60° Peak Torque Oz.-In.	Design: 6 Pole 60° Electrical Time Constant L/R (Secs.)
10C	.9650	9.5	6.5	.0004	—	—	—	—
14C	1.3400	19	12	.0007	24	.0004	—	—
18C	1.8000	35	23	.0013	46	.0007	—	—
23C	2.3000	60	40	.0022	80	.0011	—	—
27C	2.6093	71	47	.0026	94	.0013	140	.0007
40C	4.000	180	100	.0055	200	.0028	300	.0019
50C	5.000	183	120	.007	240	.004	360	.0025
70C	7.000	377	250	.015	500	.0075	750	.005
100C	10.000	545	360	.020	720	.010	—	—

Reliability
No contacts. No brushes. No commutation bars. Simplified winding. Permanent magnet.

Better Performance
Direct Drive. No friction. No ripple torque.

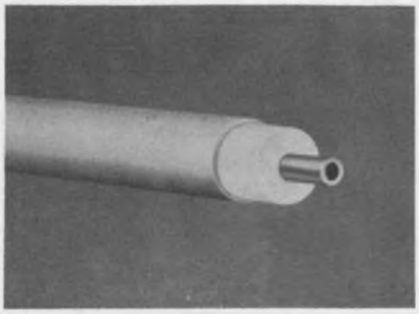
What does a Wright torque motor do?
It holds, clamps, stabilizes, drives, opens, closes, cracks, shuts, pushes, picks up, moves, rotates, nulls, controls, actuates.

Design engineers are invited to write or telephone for details. Comparison will show you that on applications where incremental rotation is needed, this new Wright concept in torquers offers substantial advantages.

WRIGHT
Division of Sperry Rand Corporation

Durham, North Carolina ■ Telephone 919-682-8161 ■ TWX 919-682-8931

ON READER-SERVICE CARD CIRCLE 106



Low-loss cable has foam dielectric

Phelps Dodge Electronic Products Corp., 60 Dodge Ave., P.O. Box 187, North Haven, Conn. Phone: (203) 239-3311. P&A: $0.64/ft; stock.

With foam polyethylene dielectric and a tubular aluminum outer conductor, "Aircraft Foamflex" is rated for less than half the loss of conventional RG-213/U and RG-214/U coax. Designated RG-231/U by the Air Force, the coax has an impedance of 50 Ω, capacitance of 27 μμF/ft, velocity of 81% and a loss of 3.5 dB/GHz. A full line of adaptors is available.

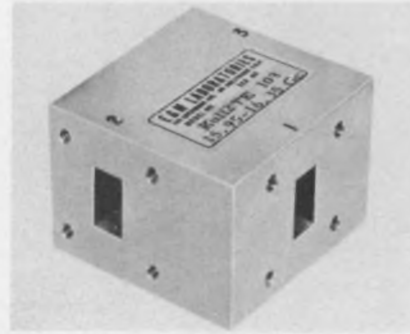
CIRCLE NO. 259

Variable attenuator covers 4 to 5, 8 to 10 GHz

Arra Inc., 27 Bond St., Westbury, N. Y. Phone: (516) 334-8710. P&A: $900; 8 wks.

Called "Space-Track" type attenuators, the model 5-6684-100C delivers 0- to 100-dB attenuation at both 4 to 5 and 8 to 10 GHz. The hand-sized unit has a power capacity of 10 W average and 5 kW peak. Other specs include a max input vswr of 1.50 and on insertion loss rating of 1.5 dB. A variety of connector-styles are offered at the customer's request.

CIRCLE NO. 260

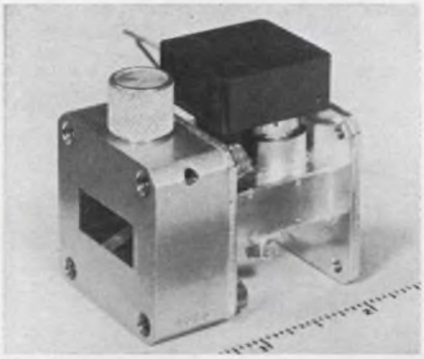


E-plane circulators cover X, Ku bands

E&M Laboratories, 7419 Greenbush Ave., North Hollywood, Calif. Phone: (213) 983-0912.

Particularly suited for duplexer applications, the E-plane "T" circulators cover the X and Ku bands. Typical of the type, the X128TE operates from 8.8 to 9.2 GHz with 20-dB min isolation, 0.4-dB max insertion loss and a vswr of 1.2 max at 100-kW peak and 100-W average power. Body size is 2 x 1-3/4 x 1-3/4-in. Units are also available in 4-port configuration in all bands.

CIRCLE NO 261



Solid-state/gas tube hybrid for radar use

Varian Bomac Division, Salem Rd., Beverly, Mass. Phone: (617) 922-6000.

Primary applications for the TR-Limiter BTL-001 are seen in radar-receiver spike elimination. The unit is a combination of a gas-switching TR with shutter and a solid-state limiter. It is designed to operate over the 9.0- to 9.4-GHz range. In addition, the BTL-001 can be used for protection of tunnel-diode amplifiers and similar units can be supplied for any 500-MHz range from 8.5 to 10.0 GHz.

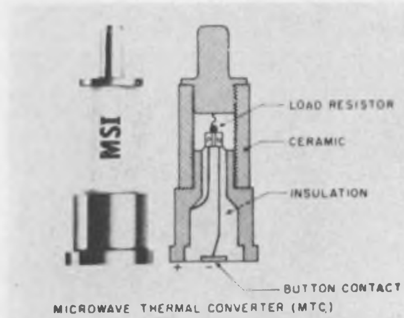
CIRCLE NO. 262

805 MHz shifter is varactor controlled

Microwave Associates Inc., Burlington, Mass. Phone: (617) 272-3000.

Designed as an error correction element in a linear accelerator, the MA-8352-2LIT phase shifter is varactor controlled. Among the component's features is a drive power requirement of 0-120 V at less than 100 μA. Phase shift is continuously variable from 0 to 180 degrees. Maximum insertion loss is 1.5 dB, vswr is 1.5 and power level is rated at 100 mW.

CIRCLE NO. 263



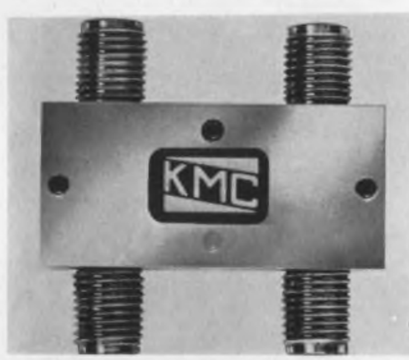
MICROWAVE THERMAL CONVERTER (MTC)
1N21/1N23 CARTRIDGE

Microwave converter goes to 12.4 GHz

MSI Electronics Inc., 34-32 57 Street, Woodside, N. Y. Phone: (212) 672-6500. P&A: $22.50 to $45; stock.

RF energy is measured by conversion to heat by the MSI series of microwave thermal converters. In absorbing RF power in the 10-kHz to 12.4-GHz range, the converter's load resistor rises in temperature, producing a dc potential through a thermocouple. This output voltage is proportional to the RF power absorbed regardless of waveform or duty cycle.

CIRCLE NO. 264



3-dB coax hybrids operate as 90° shifters

Kevlin Mfg. Co., Inc., 24 Conn St., Woburn, Mass. Phone: (617) 935-0100.

Two miniature 3-dB coaxial hybrids cover octave bandwidths as classical 90° hybrids. They can be used simply to obtain a relative 90° shift or as a part of a comparator or shifter network. Model 0-106 covers 2-4 GHz with 18 dB isolation, a vswr of 1.35 and an insertion loss of 0.1. Model 0-107 covers 4-8 GHz. Its specs are identical except it has an 0.25 insertion loss.

CIRCLE NO. 265

Pulsed X-band TWT suitable for radar

The M-O Valve Co. Ltd., Brook Green Works, London W.6, England. Phone: 01-603-3431.

The pulsed traveling-wave tube, type TWX16 for radar applications gives over 40 dB gain at 5 kW peak output power. Mean power is 30 W and saturated peak rating is 20 kW. Unit band-width is 500 MHz in the 8-9.3 GHz region. The tube is of metal-ceramic construction and it uses a ring and bar slow-wave structure that is said to limit unwanted oscillations. Helix is at dc potential.

CIRCLE NO. 266

Dispersive delays simplify PC radar

Control Electronics Co. Inc., 153 Florida St., Farmingdale, N. Y. Phone: (516) 694-0125.

A prime application area for a new line of dispersive strip lines is pulse-compression radar. In this application, the delays are said to eliminate expensive and bulky filter components, and increase both range and resolution. At compression ratios of 21, 100 and 160, bandwidths run 2.1, 1.67 and 4 MHz respectively. Delay changes here are 10, 60 and 40 μs.

CIRCLE NO. 267

Isolation switch uses electro-optics

Philco Microelectronics Div., Philco-Ford Corp., 2920 San Ysidro Way, Santa Clara, Calif. Phone: (408) 245-2966. Price: from $200 (switch), $50 (isolator).

For applications requiring extremely high levels of isolation to extraneous signals, the P651A provides simplex low-level or timing-signal switching. Output-input isolation is over 100 dB from dc to 1 GHz. Similar isolation is realized in the passband with a signal-to-noise margin of 20 dB. The switch is designed for use with the manufacturer's photon-coupled isolator.

CIRCLE NO. 268

Still the best YIG Filters available

PEL is continuing to make YIG filters built to the tightest specs in the industry. Compare specs of PEL's YIG filters and you'll find PEL's clearly superior. In L through Ku band, our dual channel units track within .1% of the tuning range. Individual channel bandwidths are maintained within 1 or 2 MHz. Linearity of better than ±0.1% is standard. High tracking accuracy makes PEL filters ideal for pre or postselection filters. Because individual frequencies can be offset, PEL YIG filters can be used as tunable discriminators. Either way, PEL YIG filters take MIL-Spec environments. PEL has the capability to produce YIG band-pass or band-reject filters, discriminators, or limiters in small quantities or in volume runs. We welcome the opportunity to quote on non-standard models too. See for yourself. Our new catalog has the full story. For your free copy, please write.

P E L

Physical Electronics Laboratories
1185 O'Brien Drive • Menlo Park, California

ON READER-SERVICE CARD CIRCLE 182

With EASTMAN 910® Adhesive...

Rubber-to-glass bonds—in seconds.

To protect the television receiver's delicate cathode ray tube during shipping and through years of normal use, EASTMAN 910 Adhesive is used to bond a protective rubber strip around the implosion shield.

The rapid set of EASTMAN 910 Adhesive is ideally suited for this production line operation. Just a few drops of EASTMAN 910 Adhesive for pennies a drop and only hand pressure gives a strong, long lasting bond.

EASTMAN 910 Adhesive will form bonds with almost any kind of material without heat, solvent evaporation, catalysts, or more than contact pressure. Try it on your *toughest* bonding job.

For technical data and additional information, write Chemicals Division, EASTMAN CHEMICAL PRODUCTS, INC., subsidiary of Eastman Kodak Company, Kingsport, Tennessee. EASTMAN 910 Adhesive is distributed by Armstrong Cork Company, Industry Products Division, Lancaster, Pa.

Here are some of the bonds that can be made with EASTMAN 910 Adhesive

Among the stronger: *steel, aluminum, brass, copper; vinyls, phenolics, cellulosics, polyesters, polyurethanes, nylon; butyl, nitrile, SBR, natural rubber, most types of neoprene; most woods.* Among the weaker: *polystyrene, polyethylene (shear strengths up to 150 lb./sq. in.).*

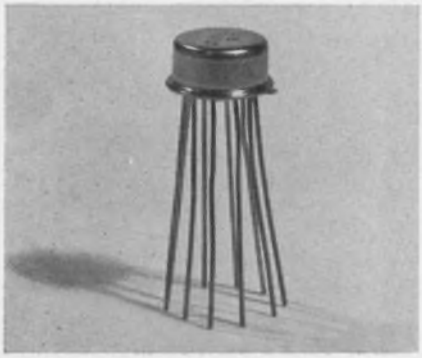
There is no adhesive like EASTMAN 910® Adhesive

SETS FAST—Makes firm bonds in seconds to minutes.
VERSATILE—Joins virtually any combination of materials.
HIGH STRENGTH—Up to 5,000 lb. /in.² depending on the materials being bonded.
READY TO USE—No catalyst or mixing necessary.
CURES AT ROOM TEMPERATURE—No heat required to initiate or accelerate setting.
CONTACT PRESSURE SUFFICIENT.
LOW SHRINKAGE—Virtually no shrinkage on setting as neither solvent nor heat is used.
GOES FAR—One-pound package contains about 30,000 one-drop applications. (Or in more specific terms, approximately 20 fast setting one-drop applications for a nickel.)
The use of EASTMAN 910 Adhesive is not suggested at temperatures continuously above 175°F., or in the presence of extreme moisture for prolonged periods.

See Sweets' 1967 Product Design File 6a/Ea.

Now available! EASTMAN 910 Surface Activator When certain surface conditions inhibit rapid bond formation, use of EASTMAN 910 Surface Activator is suggested to restore the rapid polymerization of EASTMAN 910 Adhesive.

ON READER-SERVICE CARD CIRCLE 183

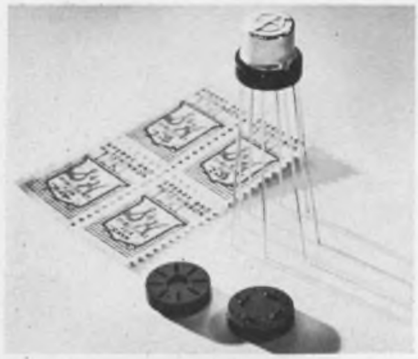


IC op-amps offset only 3 mV

Amelco Semiconductor Div., Teledyne, Inc., 1300 Terra Bella Ave., Mountain View, Calif. Phone: (415) 968-9241.

Of silicon planar epitaxial construction, the 805B and 806B operational amplifiers feature typical input offset voltage of 3 mV, with 7.5 mV as maximum. The similar 805C and 806C also have 3-mV input offset ratings but their max is 10 mV. All four types specify max supply ratings of ±18 V.

CIRCLE NO. 269

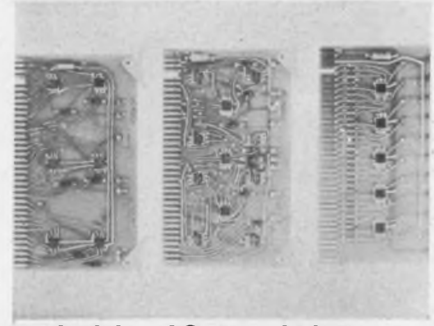


Mounting pads expand IC circles

Milton Ross Co., 511 Second St. Pike, Southampton, Pa. Phone: (215) 355-0200.

For both ease in wiring and reliability, the Transpad #10277 expands the lead-circle of TO-5 ICs and lifts the package. The pad converts the lead diameter to 0.350-in. Elevated feet permit air ventilation and allow space for flushing away excess solder flux. The pads are molded of black diallyl phthalate and meet applicable MIL specs.

CIRCLE NO. 270



Hybrids, IC modules aid system design

Information Control Corp., 138 Nevada St., El Segundo, Calif. Phone: (213) 322-6930.

A family of 5-MHz logic modules are offered to systems designers as a means of avoiding circuit-design problems. Called "Interlogic," the line features operation to 5 MHz on 5-V supplies at 2 to 25 A. All modules are mounted on PC boards measuring 3.5 x 5.75 x 0.062-in with 72-pin connectors. Components are silicon ICs or ICs and discrete components where required.

CIRCLE NO. 271

Differential amplifier in "IC cube" form

Zeltex, Inc., 1000 Chalomar Rd., Concord, Calif. Phone: (415) 686-6660. P&A: below $50; stock.

Analog scaling and buffering applications are seen for the Model 161 differential amplifier. The hybrid IC design, allowing dimensions to be reduced to 0.5 x 0.5 x 0.4-in., makes it particularly attractive where space is a major consideration. Output range is ± 10 V at 4 ma and dc open-loop gain is rated at 80,000. Gain bandwidth product is 2 MHz and frequency for full output is 150 kHz. At a band-width of 20 kHz, noise rating is 30 μV peak-to-peak. Narrow-band, 2-50 Hz, noise is 5 μV.

CIRCLE NO. 272

Micrologic cards function dc-20 MHz

Control Logic, Inc., 3 Strathmore Rd., Natick, Mass. Phone: (617) 655-1170.

A complete family of Micro Logic cards are represented in the C-120 line. Capabilities include counting, shifting and control functions at input or clock rates from dc to 20 MHz. Eight different card types are immediately available, they include multiple flip-flops and gates, an 8-stage shift register, a line driver and a crystal controlled clock unit. The C-120 line is compatible with the manufacturer's 5-MHz line, extending its capabilities.

CIRCLE NO. 273

Miniature inductors for integrated circuits

Delevan Electronics Corp., 270 Quaker Rd., East Aurora, N. Y. Phone: (716) 652-3600.

Inductors small enough to be placed inside a miniaturized package are available in the "Micro i" line. Units of the "Micro i" line range in size from 0.1 to 0.25-in. square and provide inductance ratings from 0.1 to 1000 μH. Each inductor is magnetically shielded to prevent interaction within the module and current capabilities are compatible with levels in most transistorized circuitry.

CIRCLE NO. 274

Design Aids

HUDSON WIRE COMPANY
OSSINING NEW YORK • (914) 941 8500
Single & Stranded Bare & Plated Copper & Copper Alloy

STRANDED COPPER CONDUCTOR

AWG	Construct.	Type	Lay (in. max.)	Diameter Nom.	Diameter Max.	Max. DC Resist. (Ohms/M ft. 20°C) SPC	Max. DC Resist. NPC	Weight (lbs./M ft.) Nom.	Weight Max.
4	19x7/25	Conc	3.00	.2604	.2682	.263	.274	136	139
4	19x7/25	Unilay	3.00	.2551	.2627	.263	.274	136	139
6	19x7/27	Conc	2.50	.2066	.2128	.418	.435	86.0	87.7
6	19x7/27	Unilay	2.50	.2024	.2084	.418	.435	86.0	87.7
8	19x7/29	Conc	2.00	.1644	.1693	.661	.689	54.6	55.7
8	19x7/29	Unilay	2.00	.1610	.1659	.661	.689	54.6	55.7
10	37/26	Conc	1.50	.1102	.1124	1.19	1.24	29.7	30.3
10	37/26	Unilay	1.50	.1080	.1101	1.19	1.24	29.7	30.3
12	19/25	Conc	1.00	.0888	.0905	1.76	1.83	19.2	19.6
12	19/25	Unilay	1.00	.0841	.0867	1.81	1.89	18.7	19.1
14	19/27	Conc	.88	.0703	.0715	2.80	2.92	12.1	12.3
14	19/27	Unilay	.88	.0667	.0681	2.87	2.99	11.8	12.0
16	19/29	Conc	.75	.0559	.0570	4.43	4.61	7.63	7.80
16	19/29	Unilay	.75	.0531	.0542	4.54	4.73	7.46	7.60
18	7/26		.62	.0477	.0491	6.01	6.26	5.52	5.63
18	19/30	Conc	.62	.0495	.0505	5.65	5.89	5.99	6.11
18	19/30	Unilay	.62	.0470	.0479	5.78	6.03	5.84	5.96
20	7/28		.50	.0378	.0389	9.56	9.96	3.47	3.54
20	19/32	Conc	.50	.0396	.0405	8.87	9.44	3.83	3.93
20	19/32	Unilay	.50	.0376	.0384	9.10	9.48	3.73	3.83
22	7/30		.33	.0300	.0309	15.2	15.8	2.19	2.23
22	19/34	Conc	.33	.0312	.0320	14.4	15.3	2.37	2.45
22	19/34	Unilay	.33	.0296	.0302	14.8	15.7	2.31	2.39
24	7/32		.33	.0240	.0247	23.9	25.4	1.40	1.43
24	19/36	Conc	.33	.0248	.0255	23.0	24.5	1.50	1.56
24	19/36	Unilay	.33	.0235	.0240	23.6	25.1	1.46	1.52
26	7/34		.25	.0189	.0195	38.7	41.2	0.865	0.893
26	19/38	Conc	.25	.0198	.0205	36.4	40.0	0.952	1.00
26	19/38	Unilay	.25	.0188	.0192	37.3	41.0	0.928	0.975
28	7/36		.25	.0150	.0154	62.0	66.0	0.546	0.568
28	19/40	Conc	.25	.0153	.0160	61.5	67.6	0.577	0.613
28	19/40	Unilay	.25	.0146	.0149	63.1	69.3	0.563	0.598
30	7/38		.25	.0120	.0124	97.5	107	0.350	0.367
30	19/42	Conc	.187	.0124	.0130	96.1	109	0.374	0.404
32	7/40		.20	.0093	.0096	166	182	0.211	0.224
32	19/44	Conc	.187	.0099	.0105	153	174	0.240	0.264
34	7/42		.125	.0075	.0077	258	293	0.136	0.147
36	7/44		.125	.0060	.0062	412	468	0.0875	0.0862

Stranded Conductor Construction Definitions — A central core surrounded by one or more layers of helically laid strands assembled in a geometric arrangement of concentric layers.
Unilay — Having the same direction and length of lay
Concentric — Having differing lengths and/or direction of lay

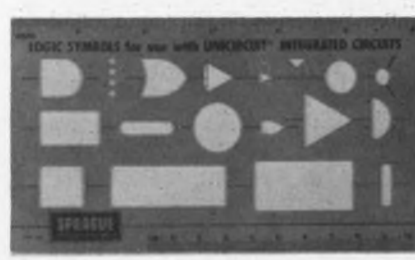
American Wire Gauge Shortcuts — Change of 3 AWG numbers doubles or halves resistance or wgt.
Change of 6 AWG numbers quadruples or quarters resistance or weight and halves or doubles diameter.

Properties of Copper — Soft, Tensile 34,000 PSI—Resistivity, 10.371 Ω CM/Ft.
Hard, Tensile 68,000 PSI—Resistivity, 10.630 Ω CM/Ft.
Break Strength, lbs = Area, Sq. In. x No. Strands x Tensile, PSI

Pocket size wire guide

A pocket size reference contains data on single-end annealed copper wire (8 to 56 AWG) and stranded silver- or nickel-plated copper conductors (4 to 36 AWG). Tables include diameter, cross-section and resistance as well as construction and lay of concentric and unilay stranded conductors. The guide also contains a summary of wire formulas. Hudson Wire Co.

CIRCLE NO. 275



IC logic template

This logic template is designed with reproductions of recommended MIL-806 symbols for use in electronic systems. The versatile template has all of the usual logic symbols AND, NAND, OR, NOR— and many other useful geometric shapes. Top and bottom edges are scaled in inches and centimeters for convenience.

Available on company letterhead from Sprague Electric Co., North Adams, Mass.


RELAY
TYPE
22AP2C05A115
COIL
CONTACTS
RELAY
TYPE
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Application Notes

Sweep oscillator applications

Twelve distinct applications for using a linear/logarithmic sweep oscillator in research and product development work, quality-control testing and production-line check-out are contained in an 8-page applications manual. Each application is presented in problem/solution form, with a simplified block diagram of the main and support instruments to be used. Typical of the simpler applications is the determination of the hysteresis or variation in output of a relay, switching circuit or dc amplifier due to a varying dc applied in a bidirectional sweep fashion. More complex applications include automatic plotting of the Fourier components of a periodic signal and the automatic display of the power spectral density associated with an arbitrary random waveform. Spectral Dynamics Corp.

CIRCLE NO. 276

Amplifier stabilization

"Practical Closed-Loop Stabilization of Solid-State Amplifiers" discusses such aspects as input capacitance compensation, driving capacitative loads and operation with boosters. Examples, illustrations and charts are included. Other topics include inside-outside followers, adder-subtracter work, full-swing capabilities, nonlinearities, noise and dynamics. A self-conducted exam completes the 30-page note. Philbrick Researches, Inc.

CIRCLE NO. 277

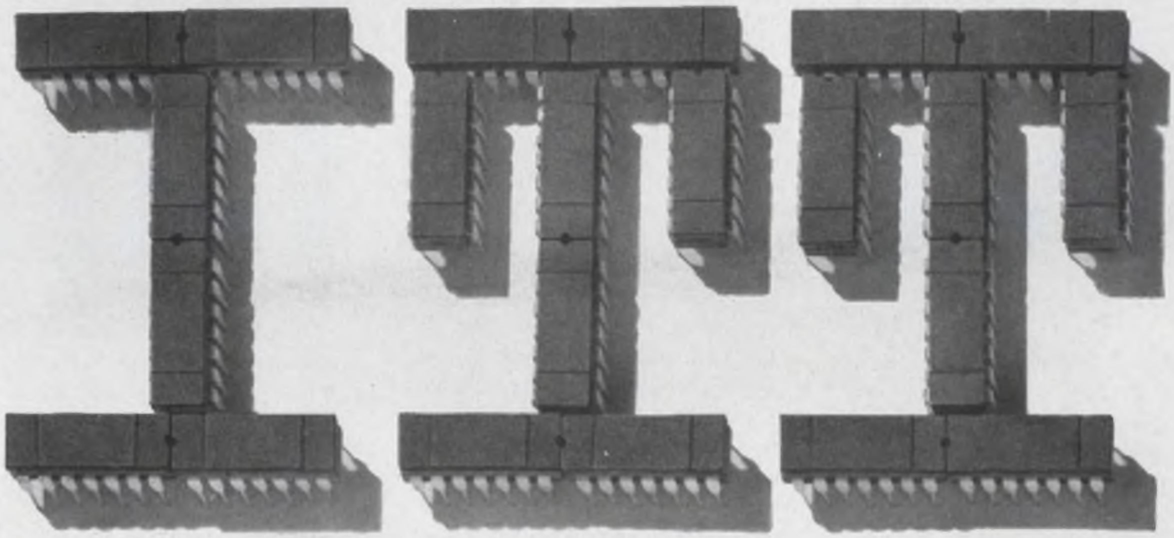
Photoconductive cells

"Selecting Photoconductive Cells" is a 24-page designer's guide which discusses considerations in the application of photo-conductive cells. The illustrated publication contains seven basic design considerations in selecting, principles and advantages over photovoltaic cells, characteristics of photoconductive materials, sample schematics using photocells and a list of typical applications. General Electric Co.

CIRCLE NO. 278

Simplify your source selection for 930 DTL

Specify



You eliminate series 930 DTL evaluation, delivery, packaging and single source troubles. Here's why:

Evaluation — Our 930 DTL circuits and test limits are identical to those of the other leading manufacturer.

Delivery — Our on-time delivery helps you eliminate manufacturing scheduling headaches.

Packaging — Your choice of dual in-line, flat pack, or TO-5 packages.

Alternate Source — With ITT added to your print, you eliminate the potential headaches of single source procurement.

Let us prove it to you. A phone call will get you off-the-shelf 930 DTL delivery from your ITT distributor. For volume procurement, ask your ITT field salesman for a quotation.

ITT SEMICONDUCTORS
3301 Electronics Way
West Palm Beach, Florida

Please send me a copy of "ITT's New Unabridged DTL Design Data Book" containing complete information and specifications on all ITT 930 DTL circuits.

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ON READER-SERVICE CARD CIRCLE 191

New Literature

Microwave catalog

This 57-page catalog includes four pages of useful microwave charts and graphs plus two information forms for switches and antennas. A plastic loose-leaf catalog contains complete specifications and dimensions on coaxial switches, waveguide switches, airborne antennas, and microwave components. Transco Products Inc.

CIRCLE NO. 279

Report on hybrid op-amps

"The New Breed Micro-Hybrid Operational Amplifiers—A Status Report" covers hybrid operational amplifier technology in some depth. This 12-page monograph explores Philbrick Researches' reasons for taking this approach and the advantages accrued by it. Philbrick Researches, Inc.

CIRCLE NO. 280

Coax catalog

Described and shown in this 24-page catalog is a complete line of coax cables, connectors, cable accessories, rigid line, delay lines and coax cable assemblies. Also included are full listings of electrical characteristics, performance and specs, and the computation methods applicable to selection of cable size and type. Phelps Dodge Electronic Products Corp.

CIRCLE NO. 281

Servo hardware

Described in this 28-page, 2-color catalog are panel-mounted dial assemblies, phase-sensitive voltmeters, phase shifters, servo clamps, and bellows couplings. Applications, specifications, and descriptive data are given. Theta Instrument Corp.

CIRCLE NO. 282

Precious metal components

Precious metal-clad precision components for the electrical, electronic and chemical industries are presented in an 8-page bulletin. In color, the brochure provides illustrations and information on strip, wire, contact tape and parts, welded assemblies, semiconductor materials and waveguide and custom tubing. Engelhard Industries, Inc.

CIRCLE NO. 283

Thermocouple alloys

A four-page bulletin describes the physical and mechanical properties of Chromel/Constantan Type E thermocouple alloys. Included in the bulletin are application data and emf reference tables. Hoskins Mfg. Co.

CIRCLE NO. 284

The tip-off

The Tip-Off is a fascinating, historically oriented periodical that is published by Schweber Electronics.

The last two issues trace the development of semiconductors. Edited by Sam Kass, the pale-blue components conjuring letter is entertaining, informative, clear and camp. Schweber Electronics, Westbury, N. Y.

CIRCLE NO. 285

Potentiometer brochure

A complete line of precision wirewound nonlinear potentiometers are described in a 4-page brochure. The brochure details functions, output equations and circuit diagrams for single and multiturn units. Duncan Electronics, Inc.

CIRCLE NO. 286

Components catalog

The entire Johnson electronic components line is described in this 26-page catalog. Prepared for design engineers, the catalog presents complete product descriptions, pictures, dimension drawings, catalog numbers, prices and mechanical and electrical specs. Products listed are capacitors, tube sockets, connectors, terminals, insulators, pilot lights, inductors and miscellaneous hardware. E. F. Johnson Co.

CIRCLE NO. 287

SCR temperature control

Use of Powertemp SCR systems in industrial temperature control is the subject of a new 12-page brochure. Information is provided on basic operating principles, selection, and operating features. Systems described control power from 1 kVa through 4100 kVa. Robicon Corp.

CIRCLE NO. 288

Step switch applications

This 10-page bulletin covers the use of step switches for programed sequence control of industrial processes. In addition to providing details on how the switches work, the bulletin includes numerous diagrams of applications and ordering information. E. W. Bliss Co., Eagle Signal Div.

CIRCLE NO. 289

Review of op-amp principles

This 20-page booklet presents a simplified introduction to operational amplifiers. Sections include the definition of terms used in manufacturer's specs, analysis of feedback amplifiers, a discussion of closed-loop gain, gain stability and frequency response and a comparison of performance characteristics for amplifier types such as chopper-stabilized, FET-input and linear IC. The report ends with a 5-page summary of common applications for operational amplifiers. Fairchild Instrumentation.

CIRCLE NO. 290

Thin-film production

A complete line of thin-film production equipment is described in a 6-page brochure. Capabilities covered include: deposition thickness control, deposition rate control, source power control, electron beam supplies, automated deposition, environment control and verification. Sloan Instruments Corp.

CIRCLE NO. 291

Core memory brochure

Called the fastest random-access large-scale memory system available, the Nanomemory 650 is described in a 10-page illustrated brochure. Among the items covered are the use of 2-1/2D selection techniques, input and output pulses and levels, electrical characteristics, timing requirements and charts and a functional diagram. Electronic Memories.

CIRCLE NO. 292

Op-amp design data

A series of design-data sheets provide information on the manufacturer's line of operational amplifiers, types 805, 806 and 807. Performance features, applications, specifications and pricing information are included. Amelco Semiconductor.

CIRCLE NO. 293

PC packaging system

A low-cost printed-circuit board system is described in an 8-page illustrated catalog. The material consists of exploded-view drawings of the system, performance charts, specifications and general descriptive material. ITT Cannon Electric.

CIRCLE NO. 294

IC system catalog

The "Chico pac" module is described in a six-page catalog. This integrated circuit packaging system is shown in terms of its capabilities in aerospace applications. ITT Cannon Electric.

CIRCLE NO. 295

NAND module system

Based on NAND logic, the 13-Series microcircuits have a noise rejection greater than 1 volt. The complete line is described in an 8-page short form catalog. A "Logic Primer" on the use of the system is also available. Canoga Electronics Corp.

CIRCLE NO. 296

Basic logic primer

A handbook to help the logic designer in logic implementation, the "13-Series Logic Implementation Primer" is intended to help both new and experienced engineers. Part one of the handbook, intended for the new engineer, describes symbology and covers basic logic rules including AND gates, inverters, NAND gates and NAND ganging. The rules of logic and logical notation, including elementary Boolean algebra are developed in this section. Part two covers the application of logic to flip-flops, "0"-level trigger control, NAND-ganging, positive load gating and special applications. Canoga Electronics Corp.

CIRCLE NO. 297

NEW LITERATURE

Silicon transistor catalog

The complete STC silicon transistor line is covered in the 16-page condensed catalog '66. Included are specs and outlines on all STC devices which include military types, pnp's, triple diffused npn power devices. The material is organized according to power ratings. Silicon Transistor Corp.

CIRCLE NO. 298

Servo components

Shaft position encoders, servo systems and components, electromechanical commutators and slip ring assemblies are all included in this 40-page illustrated catalog. Details as design features, specs, application, readout characteristics, electrical and mechanical performance and environmental specs are included for each piece of equipment listed, in addition to detailed specification charts. Northern Precision Laboratories.

CIRCLE NO. 299

Microwave oscillator catalog

A short form catalog is available describing microwave oscillators. Primary products are triode and solid state strip transmission line oscillators in L- and S-bands. Also described is a C-band coax triode oscillator. In addition the catalog includes a chart describing power capabilities. Terra Corp.

CIRCLE NO. 300

Laser warning signs

"Danger-laser light!" The message on this 6 x 8 in. warning sign gets across clearly. The handy poster is a safety must for all facilities using lasers. Hayden MicroWaves Corp.

CIRCLE NO. 301

Digital and linear ICs

A 16-page condensed catalog is a source for key features of Signetics' digital and linear IC line. Listings for each element include typical performance characteristics, schematics, power supply requirements, packaging, operating temperature range and primary area of application. The catalog is divided by circuit type and broken down within the types by operating temperature range and applications. Signetics Corp.

CIRCLE NO. 302

Miniature component catalog

A 52-page engineering catalog presents a wide selection of miniature pushbutton and rotary switches, binding posts, test jacks, sockets and module cases. Also included is such data as useful life and failure criteria, contact and insulation resistance, rotational torque or actuating force, effect of ambient temperature and effects of altitude. Grayhill, Inc.

CIRCLE NO. 303

Pot catalog

This 72-page catalog describes precision potentiometers, trimmers, dials and servo system components. The 1966-67 catalog contains photographs, drawings and detailed specifications on Beckman's complete pot line. Beckman Instruments, Inc.

CIRCLE NO. 304

ON READER-SERVICE CARD CIRCLE 197

ON READER-SERVICE CARD CIRCLE 198

Design Data from Manufacturers

Advertisements of booklets, brochures, catalogs and data sheets. To order use Reader-Service Card.

(Advertisement)

Schweber Guide To Mylar® Capacitors

The G.E. mylar capacitors listed in the Schweber guide meet the requirements of MIL-C-27287 (USAF). As with all Schweber capacitor guides, the listing is in numerical sequence by microfarads (MFD). Voltage rated at 125C, the failure rate at 90% confidence level is less than 0.1% per 1000 hours. No impregnants to leak out, no glass bushings to crack, no solder seals to fail—investigate this modern capacitor for the utmost in modern requirements.

Schweber Electronics
Westbury, New York 11591
516—334-7474

171

Engineers' Relay Handbook

A definitive work that is fast becoming a standard reference text for the relay user. Prepared and edited by the National Association of Relay Manufacturers, this book is a complete guide to the principles, properties, performance characteristics, application requirements, specifications, and testing of relays. Systems and product engineers will find the *Handbook* an indispensable help in determining the correct types of relays for their applications. For further information about this unique sourcebook, write Dept. ED

Hayden Book Co., Inc.
116 W. 14th Street
New York, N. Y. 10011

172

How To Write Technical Articles

A guide for the engineer-author, "How to Write Articles for Electronic Design" shows how easy it is to write for publication—once the engineer knows what to write and how to write it. The Author's Guide includes a complete run-down of the types of articles published by Electronic Design—plus detailed instructions on how to prepare technical articles and short special features. A MUST for every "would-be-writer" in the electronics industry. Send for your complimentary copy by circling the number to the right.

Electronic Design
850 Third Avenue
New York, N.Y. 10022

173

NEW LITERATURE

Magnetic skew effects

"Skew and its effect upon Magnetic Recording" covers the definition of skew, its effect on magnetic recording, the causes of skew and measurement techniques. Dartex, Inc.

CIRCLE NO. 305

Reprints Available

The following reprints are available free and in limited quantities. To obtain single copies, circle the number of the article you want on the Reader-Service Card.

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Dec. 7-9
15th Annual Wire and Cable Symposium (Atlantic City, N. J.) Sponsor: Army Electronics Command; J. Spergel, Wire and Cable Symposium, U.S. Army Electronics Command, Fort Monmouth, N. J. 07703

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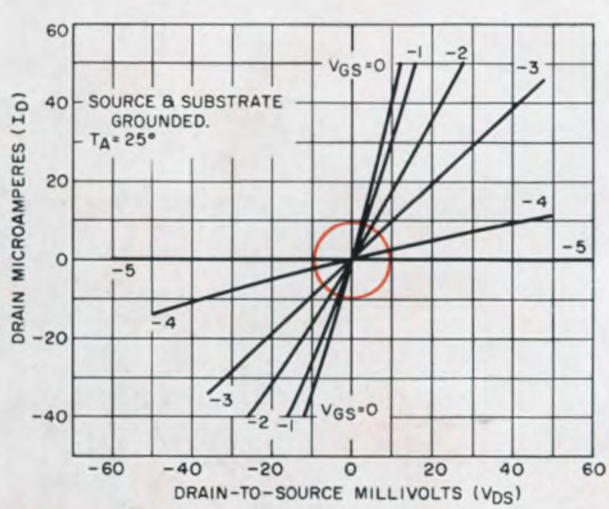

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